2013

VOLUME 35

Structural Integrity Associates, Inc.®

NEWS & VIEWS

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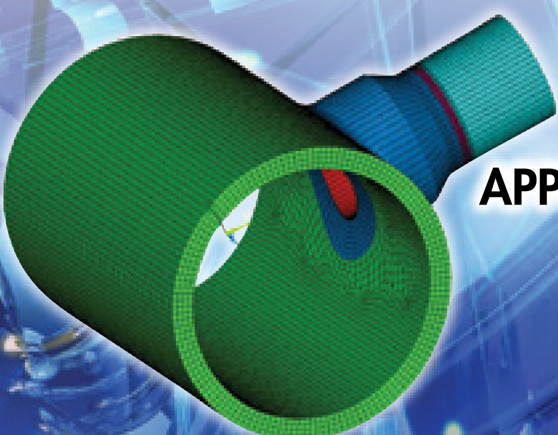

By: LANEY BISBEE
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The Making of a Consultant

One of the major issues facing our industry is an emerging knowledge/experience shortfall within the power community. We see this in our utility clients as one generation retires and turns over the reins to the next generation. Unfortunately, the generations are not contiguous in part because of the gap in U.S. construction from the mid 1990's to today, leaving one, if not two, generation gaps in staffing. Closing the gaps requires proactive and aggressive succession planning, knowledge transfer programs, and staff development commitment.

This is also true of consulting; and it's especially true for me this week as I assist in an internal consultant training program with some of Structural Integrity's most promising engineers and emergent consultants. Like any profession, becoming a competent consultant takes time. I have often described my development in terms of decades.

It took me a decade, after college, to learn to be an engineer. This period was spent on my technical development and learning something of the industry in which I worked. I was fortunate, as my first 10 years were during the power boom – high growth in electric demand driving significant construction of both fossil and nuclear plants.

This, in turn, required large OEM staffs and capabilities (I started as an engineer in Combustion Engineering's research lab – now Alstom in Chattanooga) as well as larger staffs at operating plants and plants under construction (my second job was as a plant maintenance engineer for Duke Power at the Catawba Nuclear Station). Maybe most impactful during this decade of development was the coaching and mentoring I received from truly outstanding engineers in a broad range of disciplines. In the lab, I learned materials behavior, damage mechanisms, microscopy, NDE, welding, mechanical and creep testing, fracture mechanics, and instrumentation. The transition to the plant maintenance department gave me an opportunity to develop an understanding of real plant operations, hands on knowledge of plant environments, components, repair and preventative maintenance procedures, rotating equipment diagnostics, and the daily drivers for a revenue producing power plant.

It was at this point that I went into consulting. What a transition. Engineering is not consulting! It was like starting my education all over, and it then took another decade to learn to be a consultant. Fortunately, I was again in the company of true consultants that shared their knowledge and led me though the transition. New skills had to be developed in very different competencies – technical writing, presentation skills, interpersonal interactions, business and financial acumen. In fact, at Structural Integrity we use the following to define Excellence in Consulting and we teach it in our internal staff development programs.

AT STRUCTURAL INTEGRITY, AN IDEAL CONSULTANT:

- Is a nationally or internationally known expert
- Is a lifetime student; constantly learning and growing
- Never misses a deadline
- Holds themselves accountable for their commitments
- Knows how to methodically diagnose any problem as it relates to their area of expertise
- Applies objective, critical judgment to problem solving and solution creation
- Can prepare and deliver a clear and compelling presentation
- Can also prepare a concise and authoritative written report
- Develops and maintains trusting relationships with clients
- Knows how to run or participate in a meeting with equal effectiveness
- Knows what's going on in the industry; the technical, political, and economic landscape

It's a tall order – become a respected technical expert and master the above non-technical skills – and it requires a career's commitment. But, nothing makes a consultant prouder than when their phone rings. Our clients could call many other consultants, but when they call us, they make the decades of effort worth it.

STRUCTURAL INTEGRITY ACQUIRES OWNERSHIP OF THE PICEP SOFTWARE FROM EPRI

By: BOB MCGILL
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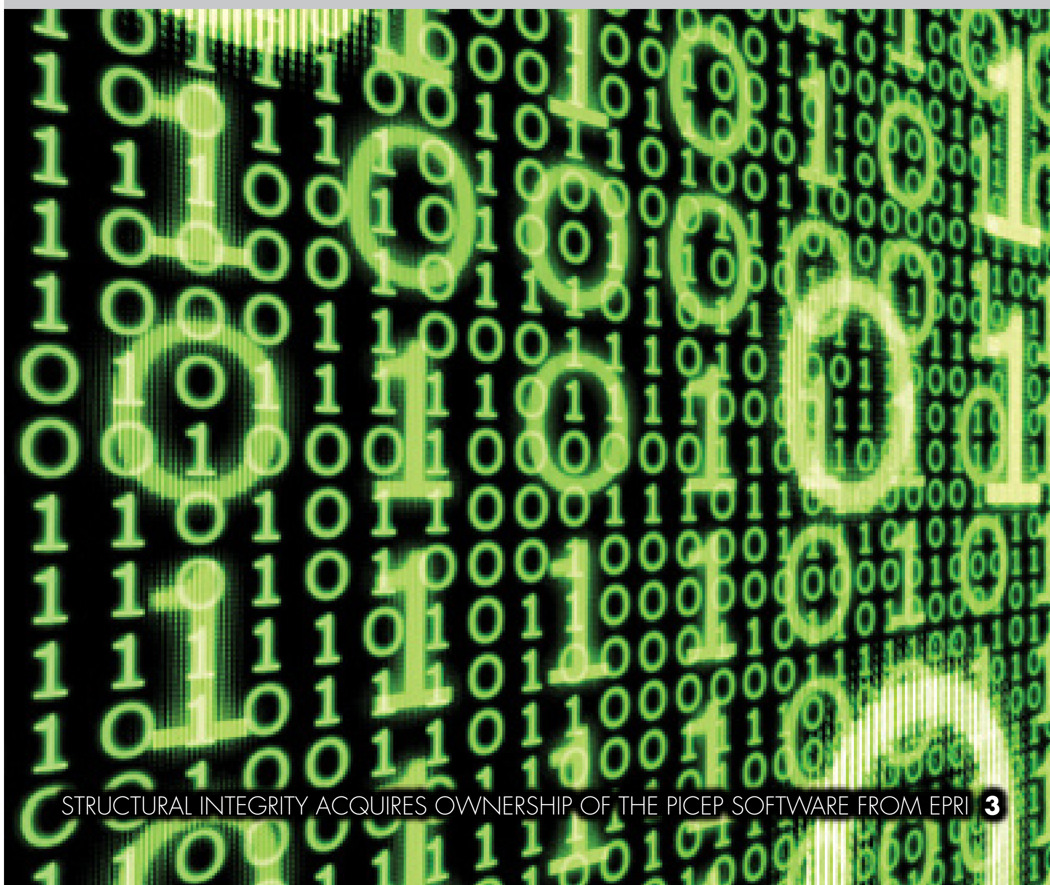
The PICEP software, originally developed by EPRI as a DOS-based product, has become the industry standard software for determining leakage through cracks. Under a recent agreement with EPRI, ownership of the PICEP software has been transferred to Structural Integrity Associates (SI). Although this software has been used in many nuclear power plant applications, EPRI developed this software as a research-grade tool. PICEP was never issued as production-grade software to be used in nuclear safety-related applications, unless additional verification and validation efforts were undertaken by the user.

Since we took the ownership of the PICEP software, we have upgraded and created a Windows version of the software which has been fully verified and validated under our Appendix B nuclear Quality Assurance program and, as such, is suitable for safety related applications. The new software product, named SI-PICEP still maintains most of the technical underpinnings of the original PICEP program. During the upgrade of the software, we identified and corrected several errors. As part of the agreement with Structural Integrity, EPRI encouraged us to make the software available in the market place on a non-discriminatory basis.

If you need further information on SI-PICEP, contact Bob McGill at rmcgill@structint.com.



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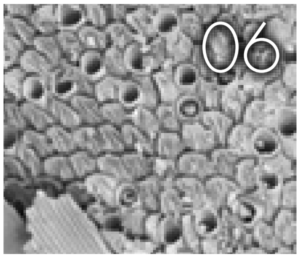

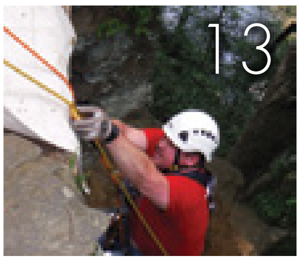

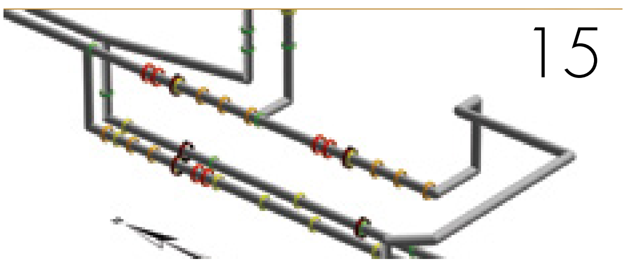

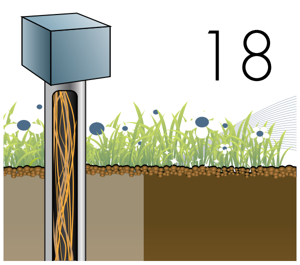

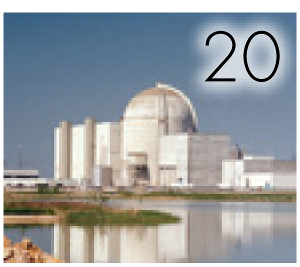

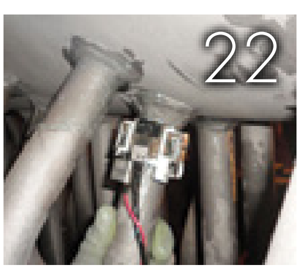

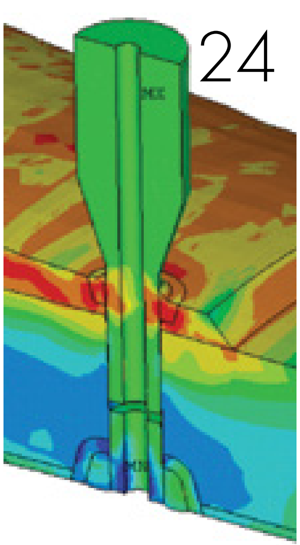


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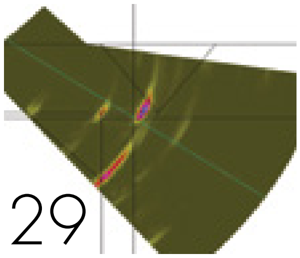
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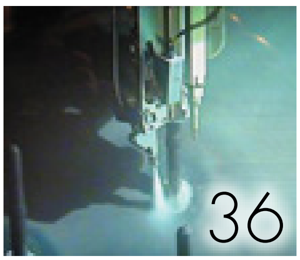
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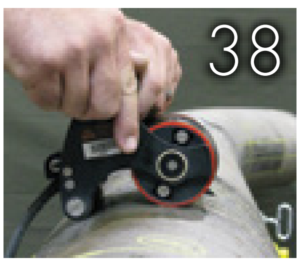
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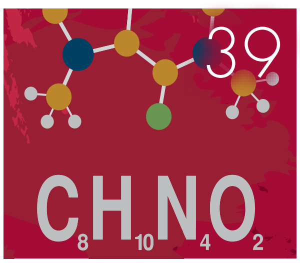
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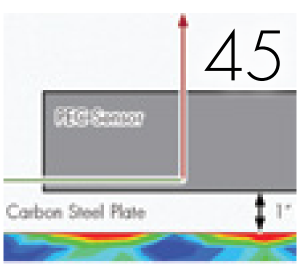
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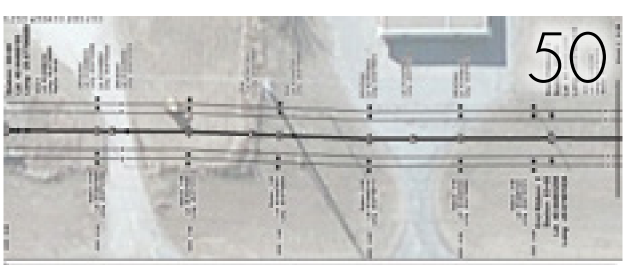
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Come Take a Virtual Tour at: http://structint.com/metallurigicallab

Thermodynamic Modeling Can Protect Your Grade 91

By: TERRY TOTEMEIER
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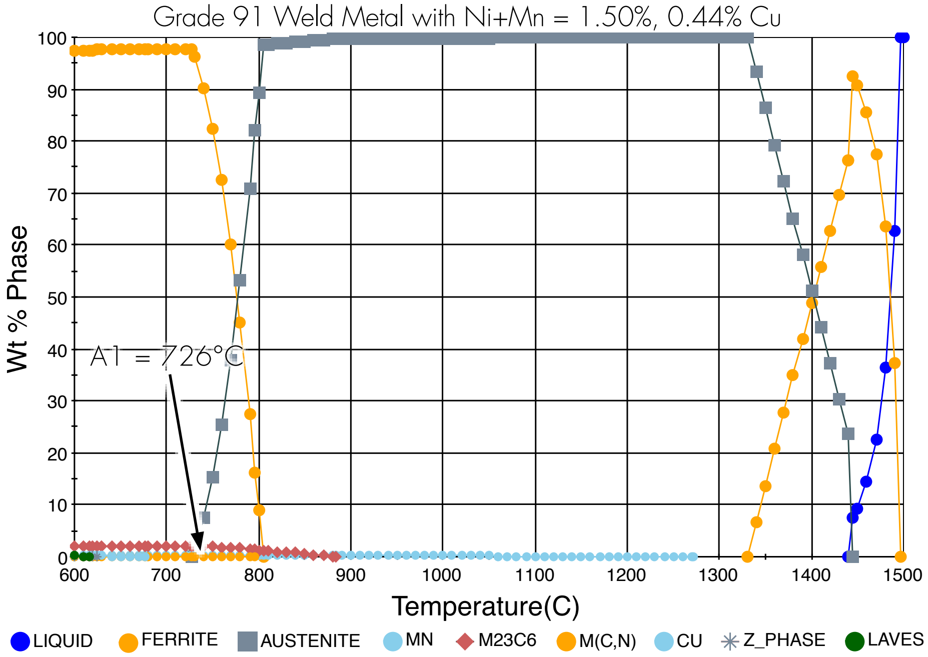
To assist with the evaluation of creep-strength enhanced ferritic (CSEF) steels, such as Grade 91, Structural Integrity uses JMatPro, a thermodynamic modeling software package. One of the uses for this software is to predict phase boundary temperatures in CSEF steels, such as Grade 91. For example; MAPro© provides the lower critical (A1) temperature in weld metal deposits with higher nickel and manganese contents. To maintain proper high-temperature creep strength in these steels, it is important not to exceed the A1 temperature of either the base metal or weld deposit during PWHT.

Typical calculation results for an actual B9-type (Grade 91) weld metal deposit with relatively high Ni+Mn (1.50%, at the ASME limit) and also significant copper content is shown in the graph below. The calculated A1 temperature is 1339°F (726°C), which is less than the minimum PWHT temperature specified in ASME BPV Sec I (1350°F, 730°C). Hence this weld metal is at serious risk of intercritical heating during PWHT, which can result in the weld metal having significantly lower creep strength than "properly" PWHT weld metal. Whether or not this is ultimately a problem for the serviceability of the weld depends greatly on the applied loading, weld preparation geometry and overall design margins. For example, in many girth welds the weld volume is sufficiently small that if the axial and bending stresses across the weld are low (hoop stress dominates), then the weld metal is constrained by the surrounding base metal. If, however, the axial or bending stresses are high then these can directly expose a weaker weld metal, although such loading can also expose the weakness of the Type IV region of the heat affected zone. Hence, all of these aspects have to be appropriately considered when performing serviceability evaluations of Grade 91 components.



Featured Damage Mechanism:

CORROSION FATIGUE IN THE WATERWALLS OF SUB-CRITICAL BOILERS

Figure 1. Corrosion fatigue cracking between a membrane and a cold side attachment.

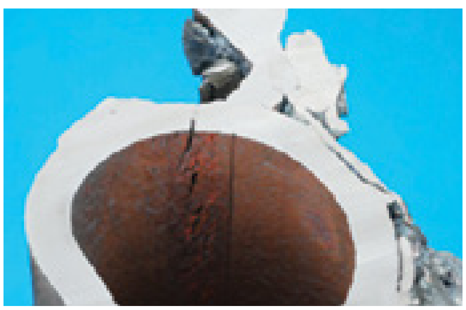


Figure 2. Cross-sectional views of the cracking shown in Figure 1. The parallel array of cracks is typical of corrosion fatigue.

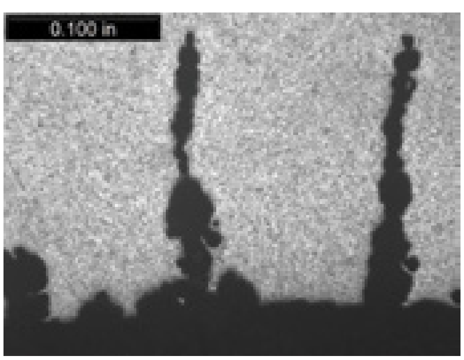


Figure 3. Microstructural features typical of corrosion fatigue cracking: corrosion and oxide bulges along the crack length and a wide crack mouth with pitting along the internal surface.

Corrosion fatigue (CF) damage in boiler tubing has been the primary cause of lost availability for over 30 years, and is a major repeat boiler tube failure mechanism in conventional fossil plants. CF is initiated on the inside tube surface, reflecting the cycle chemistry contribution to the mechanism. CF failure locations are often associated with attachments on the cold side of waterwall tubing, and most often the actual failure occurs as a pinhole leak at the toe of the attachment weld. Less frequently, failures occur along the membrane weld, either on the fireside or coldside of the tubing. The coldside failures are a serious safety issue because in many cases the tube unzips and opens out like a window, releasing large amounts of high temperature steam.

CF is a discontinuous failure mechanism that propagates through the tube wall by a repetitive oxide fracture mechanism. The magnetite that grows indigenously on the inside tube surface is a protective oxide, unless it is subjected to strains in excess of its fracture strain (about 0.2%). During normal full load operation the strain in the tube is very low, and only during certain operating regimes does the strain locally increase due to the restriction in expansion caused by the associated attachment. Experience has shown that these regimes may be related to operation features (startup, shutdown, forced cool, transient operation, trips) or due to mechanical loading by other boiler equipment (coal pipes, burner equipment).

These operating regimes are referred to as the "operating space", and the key to solving CF is to identify the harmful operating space and modify that space so that the imposed strain is below the fracture strain.

The boiler chemistry is also known to exacerbate the CF mechanism and rate, with the most important parameter being the reduction in the boiler water pH from normal operating ranges. Situations in which the pH is depressed at the same time that peak strains are imposed on the oxide are particularly harmful and need to be avoided. The images to the left show typical characteristics of corrosion fatigue cracking.

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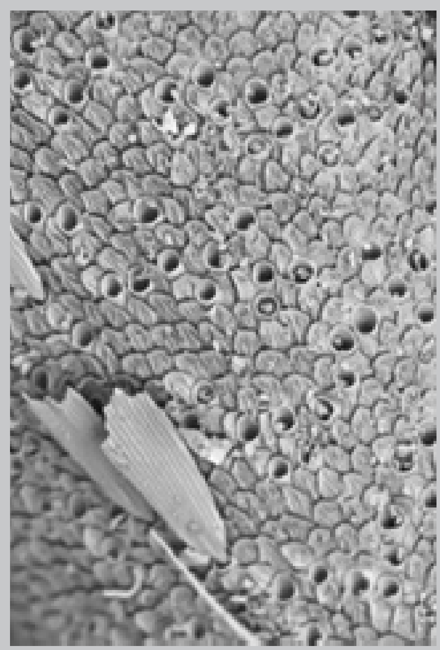
CAN YOU GUESS WHAT THIS IS?

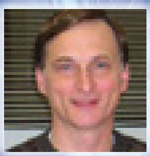
Take a look at this SEM image and see if you can guess what it is.

Hints: The original image was taken at 2000X. It is part of something that is attracted to a flame.



Answer: The surface of a moth's antennae

Managing Fatigue in a Surge Line



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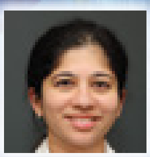

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Structural Integrity Associates, Inc. (SI) is the first organization to successfully perform a flaw tolerance evaluation to assess the operability of the critical locations of the Pressurized Water Reactor surge line at one U.S. nuclear plant using the ASME Section XI, Appendix L methodology. Appendix L was incorporated into Section XI as an alternative approach for addressing fatigue and to justify extended operation using inspections, preferably on a 10-year interval. Flaw tolerance evaluations with inspections are used to manage fatigue when the calculated ASME Code allowable cumulative fatigue usage factor will be exceeded at critical locations of the surge line, including environmentally assisted fatigue (EAF) effects. Our flaw tolerance evaluation is the first to be submitted and approved by the NRC as an Aging Management option in license renewal. This is the direct result of our continued effort in the ASME Code to get the Section XI, Appendix L approved, including our work which provided its technical basis.

SURGE LINE INSPECTION PROGRAM

The surge line inspection program relies on periodic inspections to assure the absence of cracks in the surge line welds where usage factors are high. This program augments the inservice inspections specified by the ASME Section XI. The frequency of the inspections under the surge line inspection program is based on the results of the flaw tolerance evaluation per the procedures of the ASME Code Section XI, Appendix L, "Operating Plant Fatigue Assessment." We used this alternative method to evaluate the critical locations for stability of postulated flaws and fatigue crack growth in the surge line, and to determine the required re-inspection interval, per the methods prescribed in ASME Section XI, Appendix L.

OUR METHODOLOGY

The critical locations of concern were identified where the calculated fatigue cumulative usage factors would exceed the ASME Code allowable value when EAF is considered. The methodology consists of the following tasks:

- Determine the stresses at the critical locations of the surge line, generally at the nozzles. Bounding stresses and locations were used to represent locations away from the nozzles.
- Postulate hypothetical axial and circumferential flaws at the identified critical locations. We used Appendix L specified crack models to simulate the postulated flaws.
- Perform finite element analyses to determine the detailed peak stresses and through-wall stress profiles at the critical locations due to thermal transients and mechanical loads. A portion of the finite element model for the surge line is shown in Figure 1.
- Use the stresses determined at the critical locations and the selected crack models to compute stress intensity factors for all applicable normal and upset condition loads.
- Perform fatigue crack growth analyses with the resulting stress intensity factors to determine the end-of-evaluation-period flaw size and determine the time (i.e., allowable operating period) for the postulated initial flaw to grow to the maximum allowable flaw depth.
- Determine the required successive inspection schedule in accordance with the procedures of Appendix L based on the results of the calculated allowable operating period (Figure 2).

The allowable operating periods were used to calculate the required successive inspection schedule, based on the ASME Section XI, Appendix L procedures.

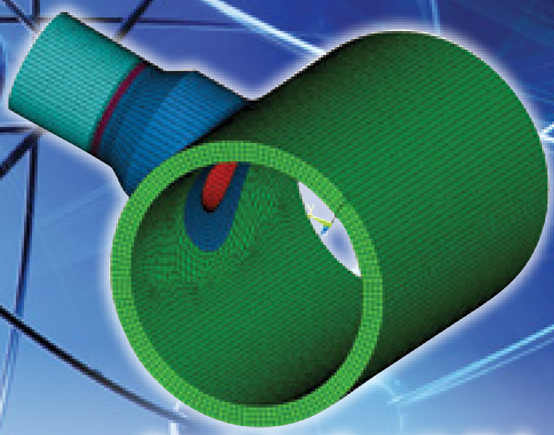


Figure 1. Finite Element Model of Hot Leg Surge Nozzle

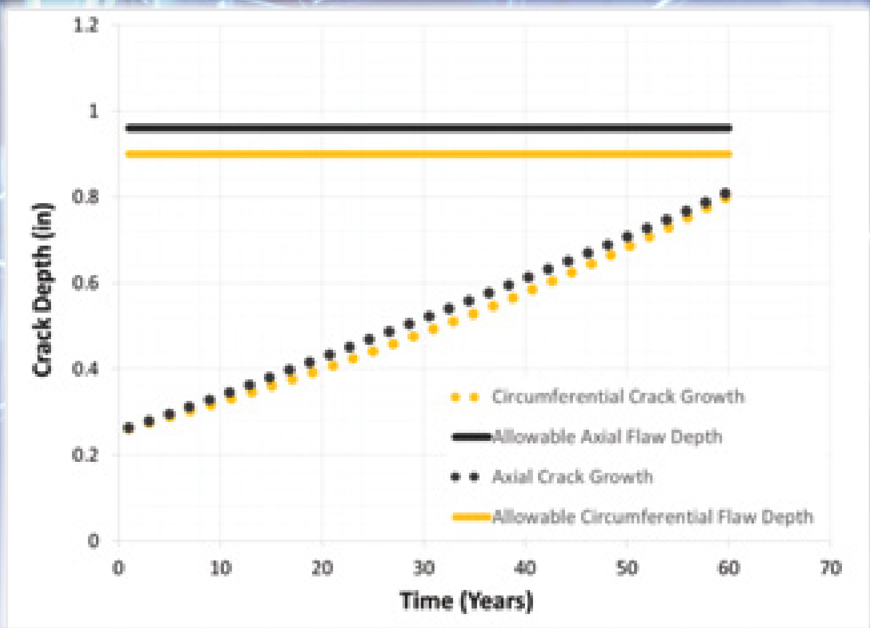


Figure 2. Predicted Crack Depth Margins for 60-year Plant Life

AXIAL AND CIRCUMFERENTIAL FLAW MODELS

Using the postulated flaw sizes and the stress distributions, environmentally assisted fatigue crack growth analyses were performed for each of the critical locations on the surge line. The assumed part through-wall flaws were grown in the depth direction, assuming a constant aspect ratio. The allowable operating period for the critical locations was calculated as the time for the postulated initial flaw size (i.e., 75% through-wall) grow to reach the allowable flaw size. Based on the calculated allowable operating period, we used the Appendix L guidelines to demonstrate that the 10-year inspection interval (already being implemented per ASME Section XI) can be maintained for successive inspections of the surge line critical locations.

20% deep flaw with a 6:1 aspect ratio (Figures 3 and 4) per the requirements of ASME Code, Section XI, Appendix L was postulated. Based on a comparison of geometry, material properties and applicable loads, the results of the detailed evaluation of the critical locations are also applicable to the other weld locations on the surge line.

After submitting the Appendix L flaw tolerance evaluation to address the license renewal commitment for managing fatigue usage in the surge lines, the NRC found that the analysis provided an acceptable approach for addressing EAF. Based on this precedent as oppossed to replacement alternatives other utilities may be interested in having Structural Integrity perform similar analyses for managing fatigue in high usage factor locations.

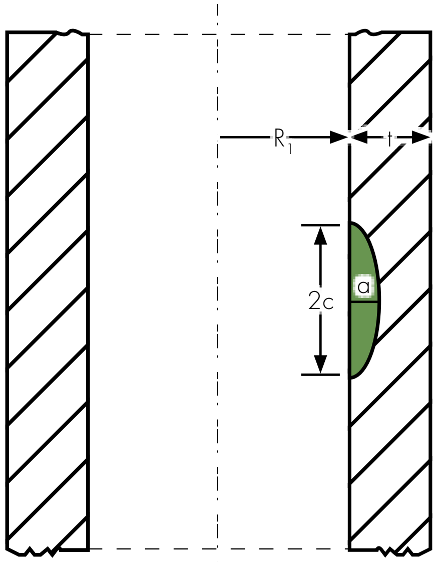


Figure 3. Axial Flaw Model

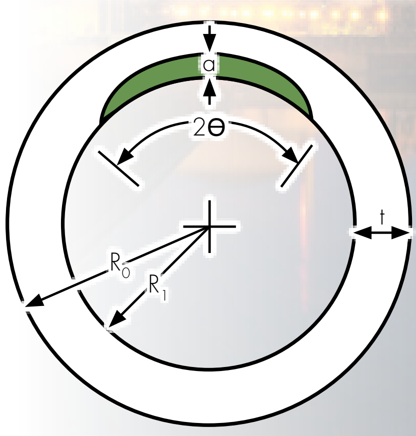
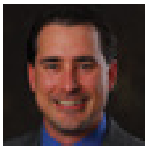


Figure 4. Circumferential Flaw Model

What's next for HRSG inspections



By: SCOTT WAMBEKE
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Heat Recovery Steam Generators (HRSGs) have evolved significantly over the past 15 years. Prior to the mid-1990s, few HRSGs operated at temperatures and pressures matching that of large conventional boilers (pressures > 2000 psig, temperatures > 1000°F). The building boom of the late 1990s was largely made up of bigger, hotter, higher pressure HRSGs than their predecessors. In addition, they were physically larger, with higher steam flows because of larger gas turbines. Finally, the piping systems of today are much more complex, using large attemperators, steam turbine bypass systems, with HRSG designers getting their first use high-grade materials (P91, T91, T23, etc). Join those facts with the operational reality that most HRSGs designed and built during the construction surge were not designed or analyzed for cycling service, but were pressed into cyclic duty by the economics of the industry. Now, this is not news to anyone that has been around the industry for a while. What is news is the evolving role of inspections in keeping the now-aging fleet of large, complex HRSG's reliable, safe and available.

Within the combined cycle plant, the large rotating pieces (gas turbine, steam turbine and generators) garner, and deserve, close attention. But that big contraption between the turbines, the HRSG, is often discounted and even viewed as a glorified radiator. Do any of these sound familiar?:

- We don't have time to open all the doors, or the drums, this outage.
- Yeah, the attemperators spray hard every startup, but pulling them out for inspection would be a big task.
- We've had over 1000 starts, but the superheaters and reheaters we can see from the inlet and firing duct and they look visually okay.
- The LP drum looks okay, but the LP evaporator tubes aren't accessible, so we've never checked their thickness or borescoped them.

HRSGs of today are complex, and pushing the limits of operating temperatures and pressures. There are more than a dozen large HRSG manufacturers worldwide, resulting in a wide variety of design details from tube harp arrangement/flexibility and supports, tube/header joint design, piping layout, circulation flow rates and velocities. Even within a single manufacturer's fleet, the designs have evolved, with major changes to heat transfer surface layout, supports and other key features that contribute to failure susceptibility.

BUT WAIT, THERE'S MORE!

Operational complexity and variance. Where the large pieces of rotating equipment have closely controlled startup and shutdown procedures controlled by OEM-supplied control systems, the HRSG often has minimal automatic controls and must be managed by the operator while he/she is doing many other things. Hang out in the control room through a few startups, and you'll see a wide range of techniques used by operators on different shifts to initiate water flow to economizers, and manage drum levels, attemperator use, superheater and reheater drain use, etc. All these can factor heavily into the consumption of component life during any given startup.

THE AGING FLEET…

Many HRSGs built during the building surge of the late 1990s are now reaching middle age. Those that have remained in base loaded service are reaching the 100,000 hour milestone, and are feeling the effects of age in fatigue cracks, corrosion and even creep damage in select high temperature components. Other cycling HRSGs of the same vintage have low hours (often 10,000-40,000), but have often accumulated more than 1,000 startup/shutdown cycles and have the component fatigue and offline corrosion to show for it.

One stark example is HP drum nozzle cracking. In 2009, drum nozzle cracks in HRSG were few and far between. Now, cracking is regularly identified in over 30% of HRSG drums with design pressure above 2000 psig and at least 1000 starts. This is definitely something better to catch early when indications are shallow and can be blended out. Once crack depth requires weld repair, the effort is arduous and expensive.

Piping corrosion under insulation and tube harp hanger rod failures by fatigue and/or corrosion were also infrequent inspection findings a few years ago, but have recently surged in the HRSGs fleet.

Until now, most HRSG inspection efforts have been largely visual…a one or two day crawl through the accessible portions of the HRSG sometimes combined with a borescope inspection from the drums and/or attemperator piping. The visual inspection is an essential part of the program, and yields invaluable data on the condition of many components such as the liner, steam drum surfaces and steam separation equipment, internal piping, tube harp headers, accessible finned tube fouling, baffles, supports and hangers. Signs that seem benign to the untrained eye (a quart of fine iron debris in the drum, for example) will tip off an experienced inspector to look harder. That iron came from somewhere, and a common cause is flow-accelerated corrosion (FAC). If more is not known, a pile like that should spur questions and actions like a chemistry and velocity profile to assess FAC risk on a component-by-component basis. Following the analysis, high-risk components can be accessed and measured directly to quantify wear and chemistry adjustments made to reduce or eliminate wear rates. If the system arrangement is such that liberated iron is transported to the HP evaporator, there is an elevated risk of deposits and under deposit corrosion. Understanding the heat flux and steam quality profile of the HP evaporator circuit is key to selecting the right area to inspect by borescope and tube sample.

STAY AHEAD

To stay ahead of damage mechanisms that threaten HRSG reliability in middle age (>1000 starts and/or >80,000 hours), a broader life management approach is suggested that collects the data from:

- Visual inspections
- Operating hours
- Chemistry profile including historic timing of program changes and excursions
- Startup and shutdown cycles
- Operational procedures
- Online walkdowns and scans
- DCS data trends
- Failure history
- Stress analysis
- Non-destructive testing

When all the factors are considered, the data stream is large and requires smart storage, organization, and analysis to identify trends that will guide procedure adjustments and inspection/repair efforts.

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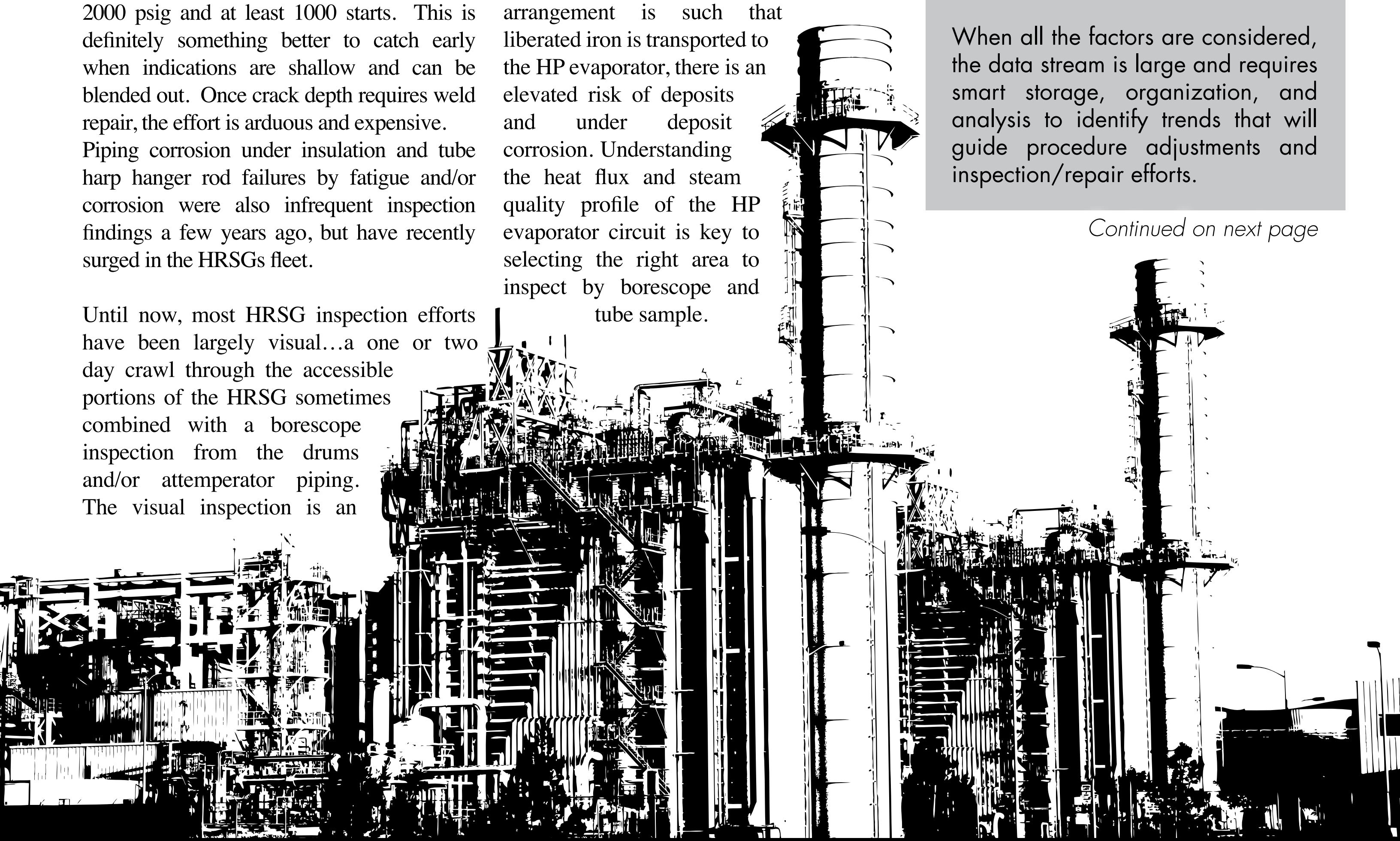


BEYOND THE VISUAL INSPECTION OF HRSG

CONTINUED

BEYOND THE OFFLINE VISUAL INSPECTION

When the information above is combined with HRSG and gas turbine manufacturer-specific issues, then we develop a list of the offline inspection tasks beyond the typical visual inspection. Some ot the common inspection locations are:

1. **HP steam drum nozzle crack checks…downcomers, risers, manways, vessel seams, etc.** Basic dye penetrant or mag particle testing can confirm cracks, but volumetric NDE such as phased array ultrasonic inspection is required to quantify crack depth and remaining life.
2. **Attemperators:**
   a. Nozzle integrity. Note that some nozzle styles are highly susceptible to ID-initiated cracks. Photo #1 shows a nozzle removed for inspection that is near complete failure. Plant personnel had not identified any failure trends prior to inspection. Note ID crack initiation.
   b. Attemperator liner cracks and distortion.
   c. Borescope inspection and phased array ultrasonic testing on attemperator steam piping including elbows and nozzles.
3. **Borescope areas at risk of FAC-related damage, but not easily accessible for direct thickness measurement.** The best way to identify areas is through a quantitative FAC risk assessment prior to planning outage work.
   a. LP and IP evaporators, tubes, headers, steam drum internals and circulation piping.
   b. Economizer components (tubes, headers, piping) of all pressure levels in the susceptible temperature range. Note that in both economizers and evaporators, physical arrangement differences may result in elevated risk areas in completely different locations under the same chemistry regime.
4. **Tube sample analysis.** There are many reasons for tube sample analysis…failures analysis, chemistry excursions causing risk to known locations, deposits identified by borescope, history of FAC and iron transport to the HP evaporator, high heat flux, critical quality concerns, age/hours, etc. Selecting the correct locations for sampling is critical. Some deposit loadings can vary greatly in tube harps.
5. **Dye Penetrant and/or Magnetic Particle Inspection**
   a. Tube-to-header joints where OD-initiated cracking is suspected. This is most often economizers, preheaters, superheaters and reheaters.
   b. Specific locations can be prioritized based on startup/shutdown and operational trends, including condensate management and attemperator overspray for superheaters and reheaters, visual identification of warped tubes, water flow at startup and during warm offline periods for economizers and preheaters.
6. **Piping corrosion under insulation and penetration seals at the roof and floor of the HRSG.** The effort often begins with vent and drain lines, and progresses to large bore piping and hangers depending, on plant history and findings.
7. **Ultrasonic thickness testing at areas at risk of FAC. Because many susceptible locations are not easily accessible, performing a risk assessment to quantify and rank susceptible areas based on chemistry and flow (single and two-phase) characteristics is the best approach.**
8. Based on operating hours, stress profile and initial fabrication and construction details, the alloy steel components of the superheater and reheater operating in the creep range should be prioritized and tested using a combination of:
   a. **Hardness**
   b. **Positive material identification**
   c. **Replication**

Many of the failure mechanisms in HRSGs have been well understood in conventional plants for many years. The unique surface arrangements, rapid startup and shutdown characteristics, multi-pressure arrangements and other HRSG-specific details make quantifying risk and customizing the inspection and repair efforts with the HRSGs fleet a challenge that requires a broader and more deliberate approach to HRSG life management.

SAFETY FIRST: INSPECTING HYDROELECTRIC PENSTOCKS

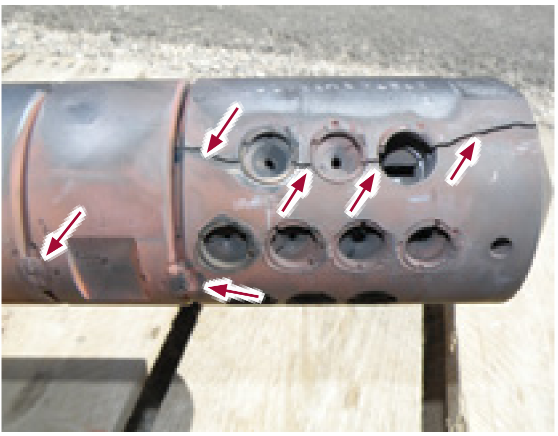
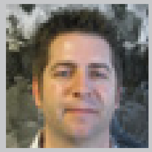


Photo 1: Cracks and missing orifice in attemperator nozzle assembly undetected prior to removal and inspection.

Photo 2: Cracks initiated on ID of attemperator nozzle at "church window" cutouts for orifices. Crack through entire assembly on face containing the section views of orifices. Cracks initiated at red arrows.



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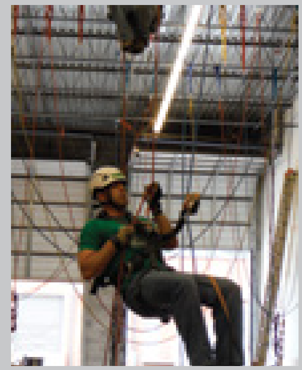
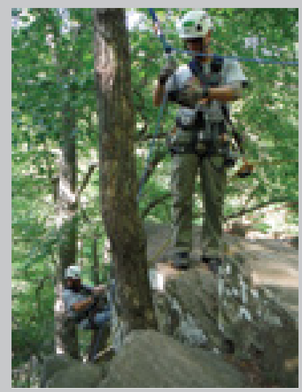
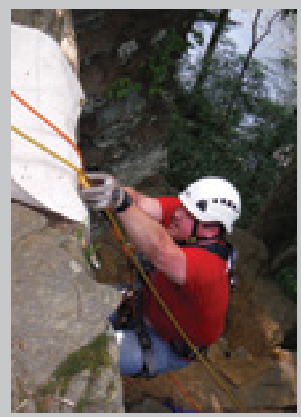


Performing non-destructive inspections on penstocks can present many challenges for Structural Integrity's staff. These challenges range from exposure to ticks, poisonous spiders, snakes and temperatures in excess of 100°F, to working in very steep mountainous terrain. Considering that the nearest hospitals are hours away from these remote locations, our personnel need to be "Safety Strong – 24/7". From the moment our employees wake up to when they go to bed, safety is always top of mind because even the slightest injury or illness in these types of environments can quickly turn into a life-threatening emergency.



In an effort to greatly reduce the chance of an injury or illness, penstock safety risk assessments are performed by our personnel during pre-job walk downs. When hazards are identified, the necessary steps are taken to either eliminate the hazard (when feasible) or reduce the risk to an acceptable level, but it does not stop here. We work from and use Job Task Analysis (JTA) templates when on a job site and daily safety tailboard discussions are held with project personnel, but we also need to be adequately trained for the job tasks.



In addition to annual health and safety training, we engaged an industrial rope access company to provide further training to educate and equip our personnel to safely inspect penstocks that are deemed "high hazard" --where a worker cannot maintain position on the slope without the support of ropes or a structure. This training consisted of a combination of classroom presentations and hands-on skills training and practice.

Ensuring we receive the appropriate training to safely complete a project is just good business.

PETE RICCARDELLA APPOINTED TO THE ACRS

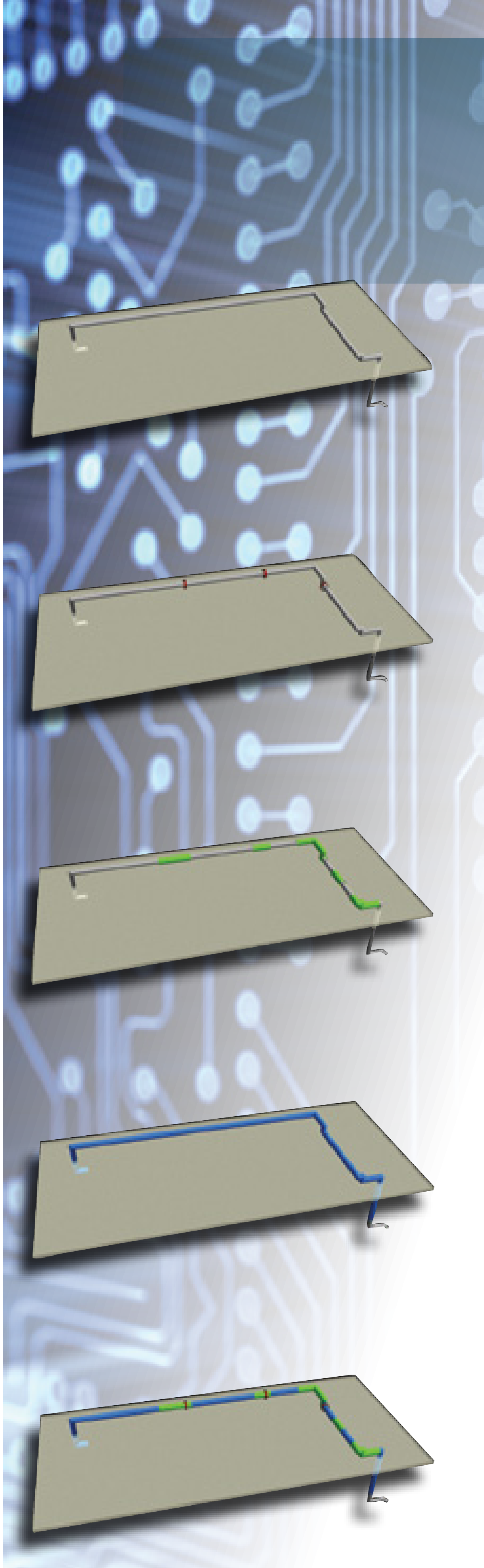
Advisory Committee on Reactor Safeguards

On June 4, the U.S. Nuclear Regulatory Commission announced that Dr. Peter (Pete) Riccardella was appointed to the Advisory Committee on Reactor Safeguards (ACRS). Pete was one of the co-founders of Structural Integrity in 1983, and served as president from the company's inception until 2004. More recently, Pete has served in a technical capacity on several challenging projects and as a member of Structural Integrity's Board of Directors.

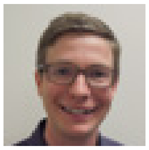
Pete has had a distinguished career, with over 45 years of experience, including Structural Integrity and several other organizations (including OEMs). He is an authority in the application of fracture mechanics to nuclear piping and vessels and has made significant contributions to diagnosing and correcting material degradation issues at operating plants. Pete earned his bachelor's, master's and doctorate degrees in mechanical engineering from Carnegie Mellon, and is a Fellow with the ASME.

The ACRS is a continuing committee established by the Atomic Energy Act of 1954. An ACRS appointment has a duration of four years. The ACRS advises the Commission with regard to hazards of proposed or existing reactor facilities and adequacy of proposed reactor safety standards and performs other duties as requested by the Commission. Similar reviews can also be requested by the U.S. Department of Energy as related to their facilities. Lastly, the ACRS, on its initiative, may conduct reviews of specific generic matters or nuclear facility safety-related items.

Congratulations, Pete!



LEVERAGING GIS FOR INSPECTIONS



By: ANDREW CROMPTON
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As the age of energy infrastructure increases so does the level of effort to manage that aging. An innovative tool for management currently used across many industries is GIS. You may have seen this tool packaged with your pipeline aging management program or used as a part of MAPProView. GIS, or geospacial information system, is being leveraged by Structural Integrity for much more.

Much of the power behind a GIS model is its unique ability to create spacial operations on the data and link different types of data with different boundaries. This is an important distinction from the static rendering of CAD software or an Access and Excel database.

For example, spacial operations can be used to answer the following questions:

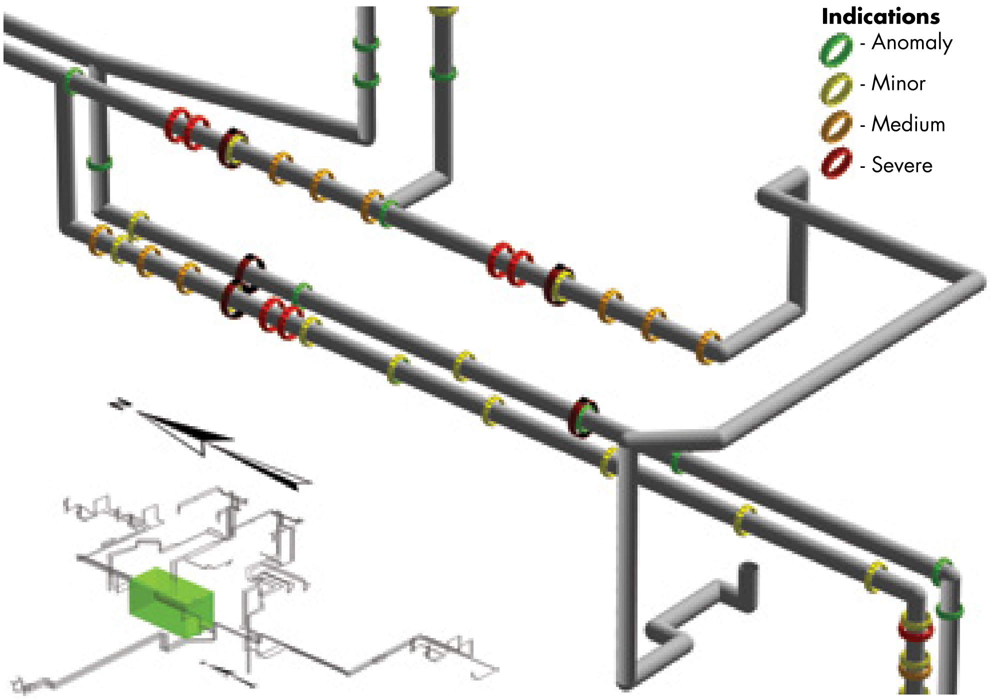
1. How many guided wave or UT inspection records showing pipe thinning have occurred within X feet of a maintenance repair/replacement activity?
2. Operating experience shows we have a potential safety or regulatory issue with process fluid A, in humid environments on carbon steel piping near tanks: which of our plants have these locations and how many locations are there?
3. During my next outage, where do I need to inspect/re-inspect, how much scaffolding will be needed, and what work areas will be affected?

The data is available to answer difficult questions--it only needs a GIS model. These models can be used for storage, manipulation, queries, analysis, and visualization. Typical types of analysis include predictive, hypothesis testing, and evaluation of program effectiveness. An added benefit is visualization, which is an intuitive way of recognizing patterns and making decisions. Decisions made from these models are supported by current and accurate program data for planning maintenance and financial support for the years to come.

If your inspection program has difficulty answering these or other project planning communication needs, consider the value that could be added by using our GIS data model and our analysis.

ADDED VALUE

- Fully characterize system degradation using all engineering, inspection, and maintenance data
- Evaluate trends and vet Aging Management Program assumptions
- Prioritize financial support using all relevant data sources
- Quantitatively evaluate program effectiveness.
- Effectively communicate the project/program to all stakeholders



LEAK-BEFORE-BREAK ANALYSIS FOR THE CNPE FUJIAN FUQING NPP UNITS 5 & 6

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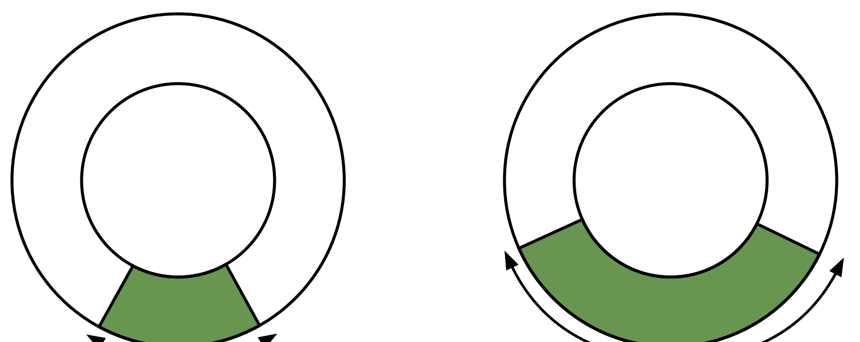
Structural Integrity is performing leak-before-break (LBB) evaluations for the China Nuclear Power Engineering Company (CNPE) Fujian Fuqing Nuclear Power Plant Units 5 & 6. Each unit is a three-loop pressurized water reactor (PWR) currently in design development. The LBB evaluations we are performing are per the guidance of Standard Review Plan (SRP) 3.6.3 and NUREG-1061, Volume 3 and include various aspects of materials, degradation mechanisms, critical flaw determination and leakage calculations. The objective is to determine if application of LBB is acceptable for several of the Fujian Fuqing piping systems. We are also providing licensing support for the LBB analyses with Chinese regulatory authorities.

The basis of LBB is described in General Design Criterion 4 (GDC-4) of 10 CFR 50, Appendix A. This regulation requires consideration of all dynamic effects associated with high energy pipe rupture (an assumed double-ended guillotine break). In early reactor designs, large pipe whip restraints and jet impingement shields were installed to protect against potential rupture of RCL piping. In the event of such a rupture, these features were designed to protect safety-related equipment from the dynamic effects of pipe whip and damage due to jet impingement. Later, additional dynamic effects, including compartment pressurization and the effects of acoustic waves and blow-down, were also considered. The design, evaluation and installation of protective features are difficult, costly and represent a serious impediment to in-service inspection and maintenance activities in operating plants.

LBB HISTORY

In the 1980s, LBB was developed by the U.S. industry and the NRC as a means to demonstrate that rupture of large piping is unlikely. Instead, detectable leakage would occur well before critical failure LBB methodology includes screening criteria to show there are no credible degradation mechanisms or brittle fracture failure scenarios. Fracture mechanics analyses are used to demonstrate leakage detection long before pipe rupture occurs. With NRC approval, GDC-4 was amended to include a statement that the dynamic effects associated with postulated pipe ruptures may be excluded from the design basis when analyses demonstrate that the probability of piping rupture is extremely low. Thus, LBB is used in a semi-quantitative manner to demonstrate the low probability of rupture in lieu of the consideration of dynamic effects associated with high energy pipe rupture. Piping systems meeting LBB criteria are exempt from pipe break dynamic effects considerations. NUREG-1061, Volume 3, published in 1985, provides NRC technical guidance for LBB evaluations. The NRC issued SRP 3.6.3 in March 1987 to provide the NRC staff a review process for LBB submittals. SRP 3.6.3 was revised in March 2007 to address new plants and stress corrosion cracking in PWRs which became an issue in the early 2000s.

In addition to demonstrating that no credible degradation mechanisms are present, material properties and loads are determined to conduct fracture mechanics evaluations for calculation of critical through-wall flaw sizes, and corresponding leakage rates. We use the results from these evaluations to demonstrate a minimum factor of two between critical and leakage flaw sizes. Leakage flaw sizes are determined using normal operating loads (pressure, deadweight and thermal expansion) while critical flaw sizes are determined using normal operating pressure (NOP) plus safe



Critical ThroughWall Flaw Length
Leakage Flaw Size (a_l)

Critical ThroughWall Flaw Length
Critical Flaw Size (a_c)

Figure 1. - LBB Acceptance Criteria

a_l = Flaw size to result in a certain leakage rate, e.g. 10 gpm
-Use normal operating condition (NOC)= (P+DW+Th) Loads

a_c = Flaw size to cause failure under applied loads
-Use NOC+SSE Loads

Criteria for LBB: $a_l/a_c > 2.0$

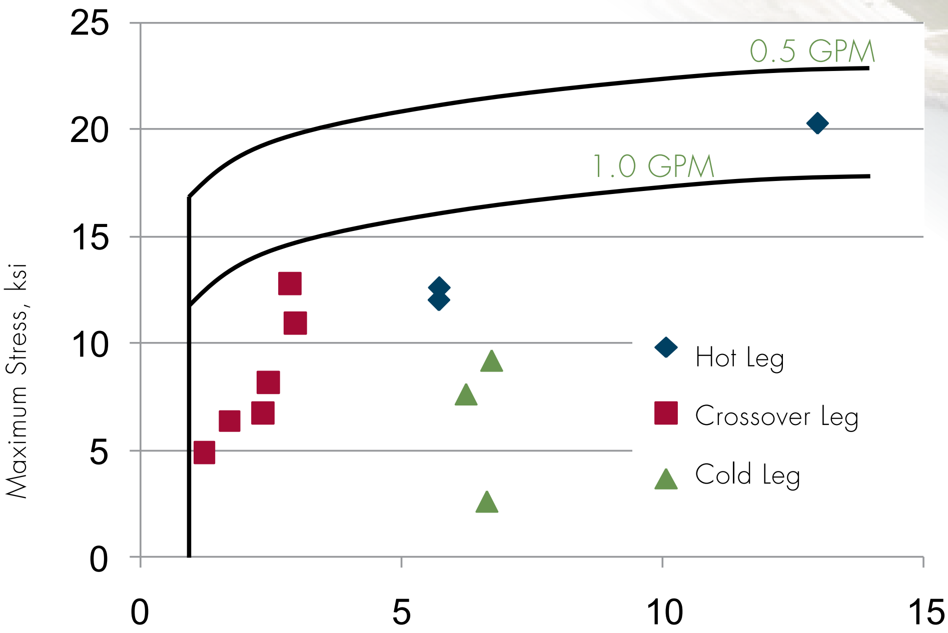


Figure 2. Normal Operating Stress, ksi

shutdown earthquake (SSE) loads. Figure 1 illustrates the acceptance criterion for LBB. The leakage flaw size is determined with a factor of ten on the leakage detection limit of the plant. As a final step, it is demonstrated that fatigue crack growth is minimal between piping inspection intervals.

For this project, Structural Integrity completed a review of material test specifications for the piping systems. Information on the piping configuration, weld locations, loads and postulated operating conditions is used to verify and document that no credible mechanisms are present. We also developed a material properties validation report, based on testing data, with material properties to be used in the fracture mechanics evaluation.

USING BAC

It was agreed with the customer that the bounding analysis curve (BAC) approach to LBB would be used. The BAC approach is an iterative approach, where initial leakage detection capability is assumed and NOP stresses and material properties are used to determine leakage flaw sizes. The critical flaw size is set equal to twice the calculated leakage flaw size and the maximum stress associated with the critical flaw size calculated. The process is repeated for another (higher) NOP stress value. The BAC is a plot of the NOP and maximum (NOP + SSE) stress pairs as shown in Figure 2.

When piping stress become available, they are plotted on the BAC curve to determine LBB acceptance, as shown in Figure 2. All points below the BAC satisfy LBB acceptance criteria while those above do not. A more sensitive leak detection which results in a higher BAC can be created to disposition points above the current BAC. Alternatively, the piping configuration can be modified to reduce the stresses to fall below the BAC.

BACs are generated for each unique combination of material and geometry. For this project, we are developing BACs for one location on each piping system. The material and design geometry combinations of the selected configurations are used to generate BAC curves. For stainless steel piping locations, critical flaw sizes are based on limit load analyses. For carbon steel piping locations, critical flaw sizes are based on crack stability analyses using EPFM, as implemented in the Structural Integrity computer program pc-CRACK. Leakage analysis for all configurations are conducted using the SI-PICEP computer program that considers two-phase flow leakage with pressure drop due to entrance effects, friction, local discontinuities and acceleration. As mentioned on page 3, we acquired the rights of the original EPRI PICEP program and have since developed a safety-related version (SI-PICEP) under our Quality Assurance Program. Additionally, fatigue crack growth calculations for assumed semi-elliptical flaws on the pipe inner surface and through wall part-circumferential flaws are being performed to confirm that fatigue growth of any pre-existing defects is not of concern.

ONGOING SUPPORT

Following the analysis of the selected configurations, Structural Integrity is providing training to CNPE engineers to support completion of the LBB evaluation of the remaining piping configurations. After CNPE engineers develop BAC curves for these configurations, we will assist CNPE in preparing the LBB portion of the plant's Final Safety Analysis Report (FSAR) and also in the licensing of the LBB evaluations with the Chinese regulatory authorities.

CORROSION RATE MONITORING PROGRAM

CoRaMPro

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Each nuclear power plant has a uniquely complex network of varying metallic buried piping that is electrically connected through the plant's copper grounding system. These conditions offer almost infinite possibilities for the existence of soil-side corrosion cells, as well as cathodic protection (CP) current collection areas.

Over the past decade, the license renewal process has focused more attention on the issue of external corrosion control for buried piping systems, many of which are now well over 30 years old.

The national pipeline industry has produced a large portion of today's standard corrosion control technologies for the evaluation and monitoring of buried pipe and structures. But the nuclear power plant grounded piping network environment does not emulate a single isolated pipeline, and the more testing that is conducted on what takes place underground in a power plant, the better these conditions will be understood.

Monitoring for corrosion conditions and CP levels should be performed at specific plant piping locations and at pipe depth to minimize errors in the measurements. And to fully understand this information, generic data should also be gathered from monitoring coupons supporting tests that independently simulate the plant grounded piping network environment with known ratios of steel and copper mixed metal couples.

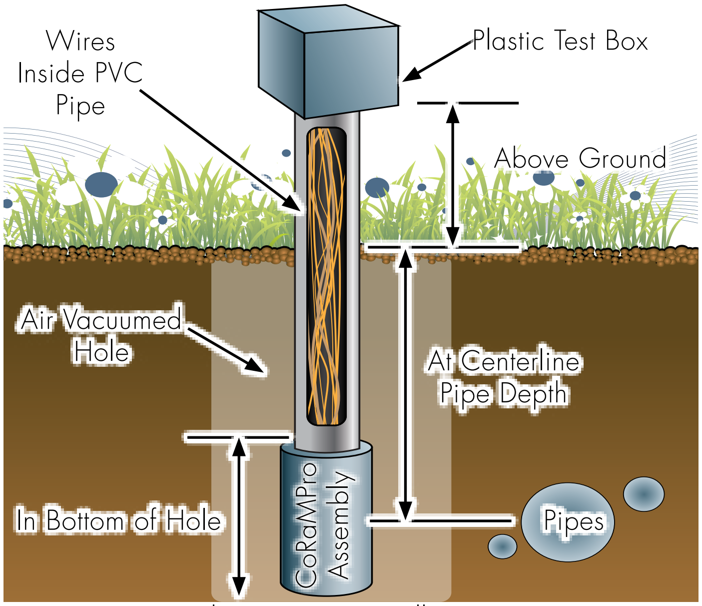
CoRaMPro

Structural Integrity (SI) has created a corrosion rate monitoring program, called CoRaMPro, which satisfies both of these monitoring needs. With CoRaMPro, it is possible to clearly define and interpret the effectiveness of existing plant CP. CoRaMPro can also gather the information necessary to establish whether or not a plant needs CP, and if CP is or will be applied, the plant can document how much CP current is required to reduce the corrosion rate of steel to acceptable levels.

THE BURIED PORTION OF THE CoRaMPro ASSEMBLY HAS MANY INDIVIDUAL TESTING PARTS:

- A permanent Cu/CuSO4 reference electrode (CSE) for taking potential measurements at pipe depth.
- Pipe grade steel electrical resistance probes will monitor corrosion rates.
- A zinc bar anode is used for verifying the reliability of the CSE, providing low levels of protection current in CP criteria testing, and is part of determining a plant's CP current density at the CoRaMPro installation location.
- A packaged magnesium anode provides corrosion control current to the CoRaMPro assembly parts when necessary.
- Soil moisture blocks will measure conditions at testing depth.
- Steel pipes with known bare metal surface area act as coupons in a variety of CoRaMPro tests.
- Short bare copper pipe sections and solid copper wires with varied bare lengths are also used as testing coupons and support other tests.

The CoRaMPro test box is set up with simple ON/OFF switches to conduct the many possible tests. Installation of the monitoring assembly can be in a piping inspection excavation, or, as is shown in the accompanying figure in a dedicated air vacuumed hole. The air vacuum approach allows several other corrosion control related tests to be performed during installation.



Typical CoRaMPro Installation Layout

The CoRaMPro test box will be electrically connected to two plant ground cable connection wires brought in to facilitate the local corrosion condition and CP performance tests that relate to the site's underground piping.

The nuclear power plant operator may only currently conduct an annual CSE potential survey of the plant piping CP state with readings taken on the soil above the areas where piping is known to exist. So why should a plant pursue a more intensive level of data collection?

❶ MINIMIZING MEASUREMENT ERROR

CSE readings taken at grade above a group of multiple pipes that are electrically connected to the plant copper grounding grid may not accurately indicate conditions five or more feet underground. CSE potential measurements only provide an indication of voltage, and depending on what method of interpretation is used, these CSE indications are then referenced to a simple go, no-go, CP criterion in order to suggest if adequate CP has been achieved.

❷ DEMONSTRATING CP PROTECTION

To increase the reasonable assurance of integrity at the plant, the operator should know the reduction in corrosion rate on buried piping resulting from the application of plant CP. And to fully understand what this means requires knowledge of how specific bare surface area ratios of buried electrically connected steel and copper interact to produce CSE potential readings and corrosion rate reduction data. The CoRaMPro monitoring assembly can provide all of this critically important information to the nuclear power plant operator.

❸ VALIDATING COATING CONDITION

If monitoring is installed a few years in advance of planned excavations, the data gathered can be compared to the exposed pipe condition once excavated. With this type of data validation, the conclusions drawn with respect to buried pipe at other locations around the site can be made, possibly saving the site millions in unnecessary excavation and inspection costs.

HRSG USER'S GROUP HONORS 2013 STEAM PLANT MENTORS

Expertise and industry involvement are a source of pride at Structural Integrity. These qualities also took center stage at the HRSG User's Group 21st Annual Conference and Exposition.

At an awards ceremony held April 30th in Tampa, Florida, the HRSG User's Group honored five key members for their loyal participation and significant contributions. Each recipient was named a "Steam Plant Mentor" and presented with a commemorative plaque inducting him into the Class of 2013.

Among those honored was Structural Integrity's Dr. Barry Dooley, an expert in HRSG reliability, metallurgy and more. Dr. Dooley is also an honorary fellow of the International Association for the Properties of Water and Steam and is the author or co-author of more than 260 papers.

Congratulations to all of the HRSG User's Group 2013 Steam Plant Mentors:

- Barry Dooley
- Jorgen Gertz
- Tate Hawkins
- Earl Thomas
- Peter Allison

INSPECTING FOR CONTAINMENT LINER CORROSION

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The large buildings, supports, and other "civil structures" at nuclear plants have a number of things in common. First, all are built on site using reinforced concrete construction. This may be pre-tensioned, or post-tensioned. Most of those structures are large: 100 feet or more in diameter or horizontal dimension and 100 to more than 200 feet tall. All such structures that must confine radionuclides will have a metal liner. The simple reason for the liner is that while the concrete provides an excellent structural solution for spent fuel pools or containment buildings (typically the large round buildings in the accompanying photos), concrete will not be 100% leak tight to gases and liquids an extremely important function when radioactive materials are involved. The lack of absolute leak tightness of concrete and other rocks is something to remember the next time the fracking folks talk about the impermeable layers of concrete and rock that will always keep their fluids out of aquifers and other critical parts of the environment.

Inspecting large and diverse components that have a critical function (e.g., a containment liner) for flaws that can be very small (i.e., that will provide a leak path) presents an obvious challenge.

Providing an **Inspection Basis for Structural Integrity** always presents a challenge in terms of properly identifying the extent and severity of any degradation. However, demonstrating the structural integrity of the containment liner, even in a degraded state, will be relatively straightforward since the normal and off-normal environments to which the liner has been and will be exposed are relatively benign. That is, the containment liner has only a minimal structural function and that should not be degraded very much in service.

The **Inspection Basis for Leak Integrity** is another matter. The primary purpose of the steel liner is to provide a leak barrier between the inside of the containment and the environment, acknowledging that concrete is not impermeable to gases and liquids that could be released to the interior of the containment during a design basis event. Demonstrating reasonable assurance of leak integrity (i.e., there are NO leak paths) will require that individual inspection volumes are sufficiently fine and that appropriate statistical approaches are applied.

Structural Integrity has a long history of providing assessments of the condition of carbon steel structures that are degraded by corrosion, including containment liners. SI has performed such characterizations in nuclear plants in other large systems such as service water system piping, including safety-related service water piping, and continues to characterize the condition of a number of old or buried penstocks for our hydroelectric clients.

A typical approach will involve a multi-disciplinary evaluation involving corrosion engineering, high-tech inspections, and structural assessment of the results. The methodology relies upon an understanding of the potential degradation mechanisms, how those mechanisms can be affected by operational variables, inspection (using appropriate and sometimes ever-improving NDE tools), application of statistics during the selection of inspection locations, and proper processing data obtained from the inspection. In conjunction with an inspection location selection process, which aims to define a sufficiently large and diverse sampling of locations, our process yields a highly reliable characterization of general corrosion, pitting corrosion, and other effects for the system as a whole by examining a sample of reasonable size.

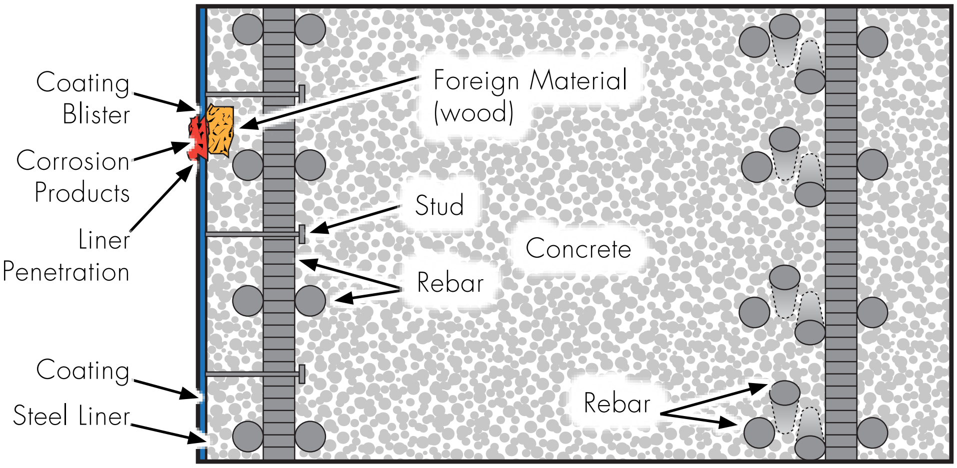
Corrosion at Carbon Steel Containment Liner-Concrete Floor Interface

CONTAINMENT VESSEL LINERS

Containment vessel liners add another twist. The inside of the liner (the side of the steel away from the concrete and toward the reactor vessel, et al.) may have been exposed to water sprays or standing water for some period of time. That corrosion may be visible, but characterizing its depth or extent requires quantitative tools that can inspect otherwise inaccessible areas such as those that exist at and below the level of the floor. In addition, several plants have experienced through-wall corrosion of their containment liners from the concrete side, always as a result of corrosion due to foreign objects such as wood or leather having been left in the concrete creating the highly undesirable small anode/large cathode condition for galvanic corrosion. That "backside" degradation clearly requires volumetric inspection tools.

The statistically based approach to sample selection and inspection seeks to capture a sufficiently extensive and random sample to ensure a 95/95 confidence level (i.e., a 95% probability that there are no viable leak paths or incipient leaks at 95% confidence). Note that 99/99 or other confidence levels can be achieved-only the number of samples and the requirements on the number of negative findings change. Both effects will increase the inspection time. The approach will include a inspection location bias toward the expected worst case damage, for example, toward the bottom of the containment liner/vessel where water may have collected and remained for extended periods, but will (and must) also include areas considered "typical" and will sample from all areas of the containment to assure that the sampling is sufficiently broad.

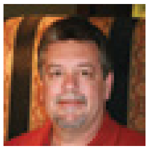
Corrosion at Carbon Steel Containment Liner-Concrete Floor Interface and Top of Lowest Liner Panel



Schematic of a reinforced containment cross-section showing embedded foreign material and containment liner corrosion (from D. Dunn, 15th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors)

Recommendations on locations for inspection must always include accessibility considerations. Although the number of individual thickness measurements required to provide sufficient data to address the 95/95 confidence level cannot be determined precisely until the initial inspections are completed (i.e., the inspection results will dictate the number of areas that qualify as definite negatives; and only then can the 95/95 conclusion be reached), it is anticipated that inspection work during a single outage window will provide access to a sufficient number of liner sections to provide a sufficiently large and diverse sampling. The primary consideration that may not be addressed by inspection during that single outage window is most likely to be associated with an adequate sampling of liner locations at the highest elevations, which are, of course, difficult to access.

ADVANCED PHASED ARRAY UT EXAMINATION OF HEADER STUB TUBE SOCKET WELDS



By: DAVE OVERTON
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Figure 1. Typical Stub Tube Welds

Stub tube welds connect terminal tubing to headers (Figure 1). These welds are basically partial penetration welds or filet welds attached to the header via countersunk 'j' groove weld prep in the header (Figure 2). During service these welds can experience creep-fatigue, or in some cases oxide jacking and this can initiate cracking on the surface and subsurface on the header and tube side of the weld. Traditionally, a magnetic particle examination is usually conducted for the surface breaking flaws. If left undetected, the cracking can lead to total ejection of the terminal tube, causing a very violent failure and possibly significant collateral damage as well.

Historically ultrasonic testing (UT) of socket welds was conducted using conventional off-the-shelf probes and sensors. Due to the inherent geometric features associated with the socket weld stub tube, positioning of the UT probe was such that a major portion of the effective energy was being dispersed around the tube (Figure 3 on next page). In 1993 Structural Integrity introduced the first advanced stub tube UT inspection technique based on acoustical focusing techniques more commonly used in laboratory environments (also Figure 3). The proprietary design and methodology developed by Structural Integrity controlled the ultrasonic beam formation such that only a minimal amount of energy would be affected by the tube geometry, resulting in a significant increase in detection and characterization capability for damage initiating at the root of the socket weld. Adding to the benefits derived from this unique probe design, SI introduced fully encoded and digitally recorded B-scan imaging using the TestPro™ ultrasonic test system.

With the introductuction of phased array ultrasonics in the early 2000s, we adopted this methodology in lieu of conventional focused UT for these examinations and a good number of our other examinations. A sectorial scan using a range of angles (30-80 degrees) simultaneously interogated the weld. This technique improved the efficiency of the examinations while providing an image of the weld, which helped with interpretation. Instead of a raster scan, a single circumferential line scan could now be employed to examine the welds. This phased array examination continued to be performed manually, which left interpretation and classification up to the individual operator.

The recording criteria was a classification system based on estimated throughwall and radial extent of the indications in each quadrant of the circumference of the weld. Once all the numbers were added together a ranking system was employed to determine priority for repairs. A screen shot image of some of the worst recorded

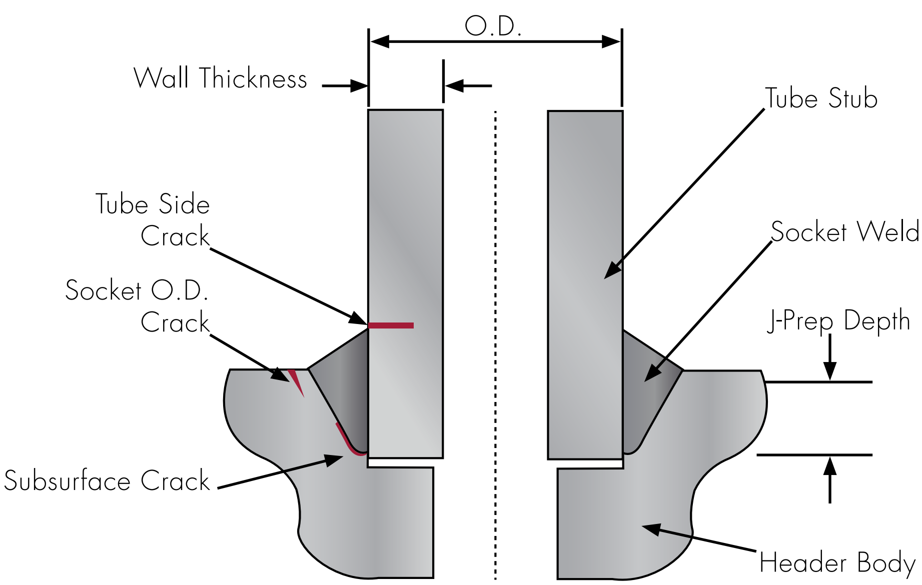


Figure 2. Stub tube weld J prep

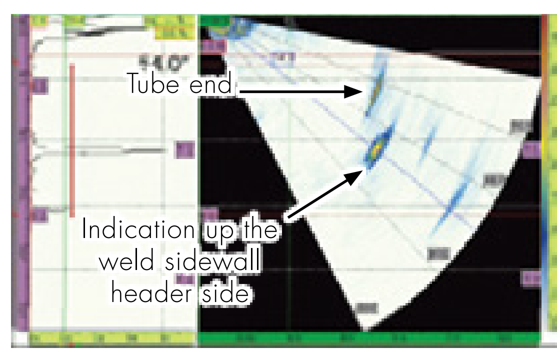


Figure 4. Phased Array Sectorial image of a screen shot of a Stub Tube weld

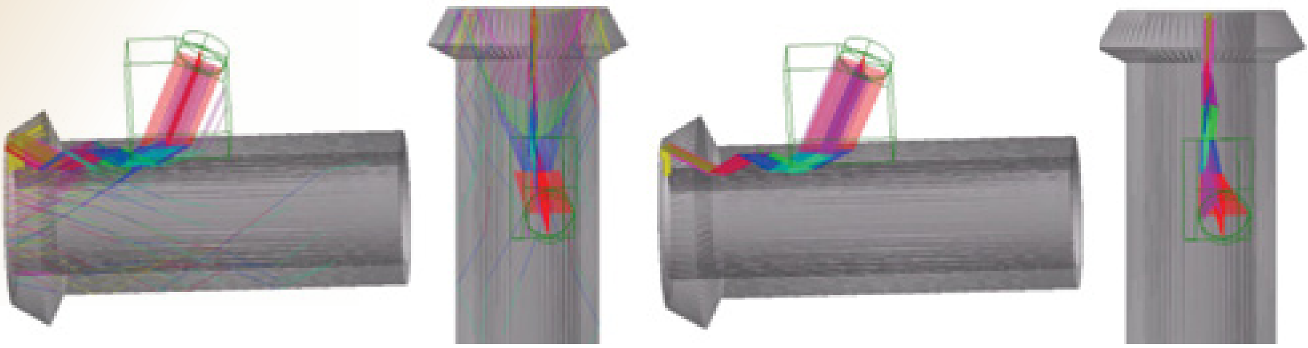


Figure 3. Ultrasonic Beam Simulations – Normal dispersion shown on the left; Focused beam shown on the right

indications was also provided; however, this offered little information concerning the extent of the damage (Figure 4) since it is taken at a single point around the circumference.

Based on inconsistent evaluations of these welds, it was determined that recording the entire examination would help to improve the quality of the examinations.

Using a bracelet scanner (Figure 5) that we developed internally, we are now able to provide 100% encoding of our examination of these welds.

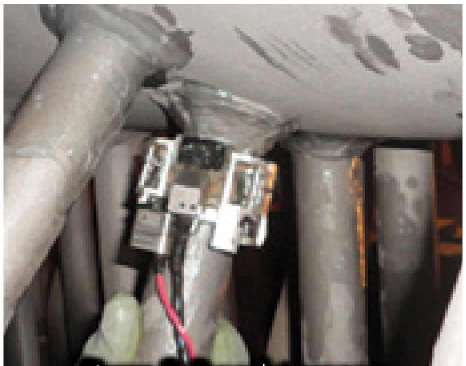


Figure 5. Bracelet scanner

This provides for offline analysis of the collected data and also creates a permanent record of the examination for future comparison. In addition to these advantages, actual length and through wall extent of the flaws detected can be derived easily from the data.

The opportunity to utilize the encoded scans for these examinations occurred this past spring. One of our clients had over 700 stub tube welds to examine. These welds had been problematic for the client for several years, having caused multiple failures and costly forced outages.

We put a plan together to provide the best possible examinations for the client. Modeling of the geometry of the weld was performed to show coverage extent based on known geometry (Figure 6). We optimized the software used to analyze the data to provide the most comprehensive information of the ultrasonic data of the component.

Collection of the data was accomplished utilizing two-man crews. Data collection went better than anticipated with a production rate average of two minutes per weld. As the data was collected two data analyst reviewed and recorded it. Once the data analysis was complete, a map of the results was developed based on severity of damage that was found.

THE RESULT

Several welds were found to contain significant cracking that were repaired immediately. Figure 7 shows a typical data presentation of a weld with significant damage. Figure 8 shows the as found condition of one of the welds during repair, confirming cracking just below the surface and extending to the seat of the weld.

Performing these examinations utilizing our bracelet scanners proved to be very efficient and provided very accurate data. This also provided the client with confidence in the results and a permenant record that can be used for future comparison or referenced when questions arise concerning the examination results at a future date. Structural Integrity believes that encoded examinations provide results that are far superior, to more conventional approaches allowing enhanced visualization and a future reference which enhances overall quality.

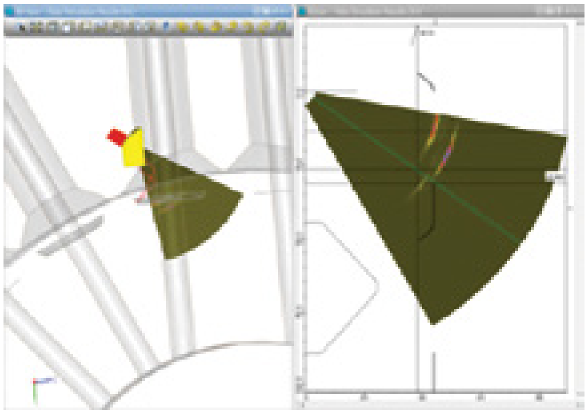


Figure 6. Modeling of the stub tube welds

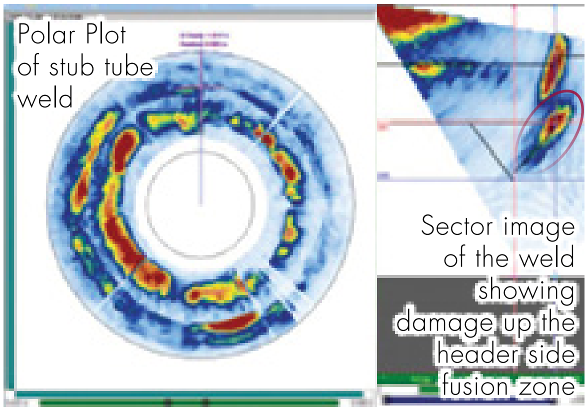
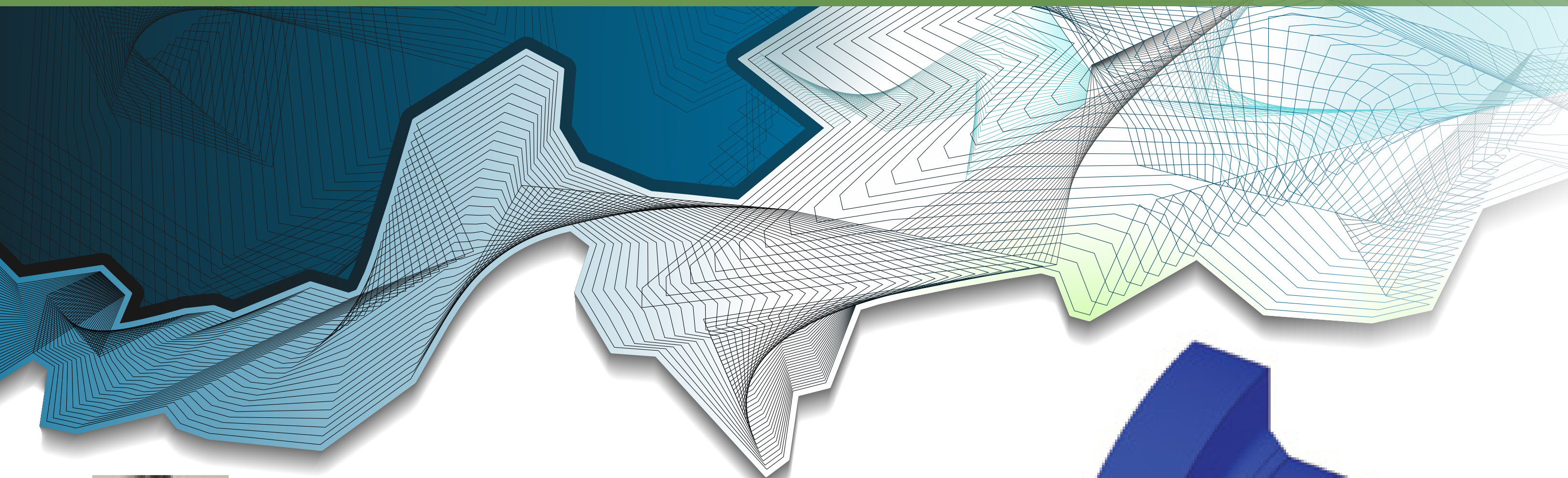
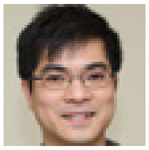


Figure 7. Typical data presentation

Figure 8. Confirmed crack

WELD-INDUCED RESIDUAL STRESS FINITE ELEMENT ANALYSIS MACROS FOR ANSYS





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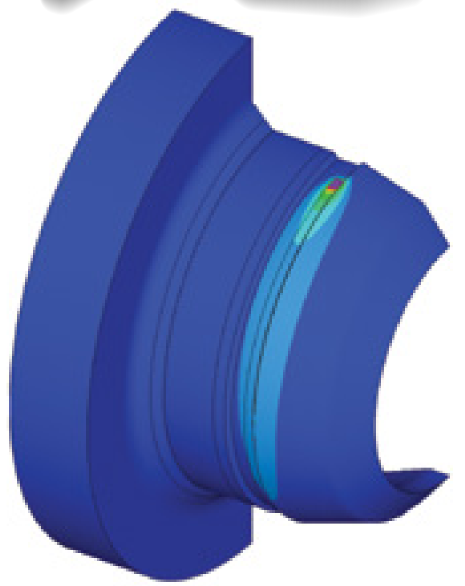
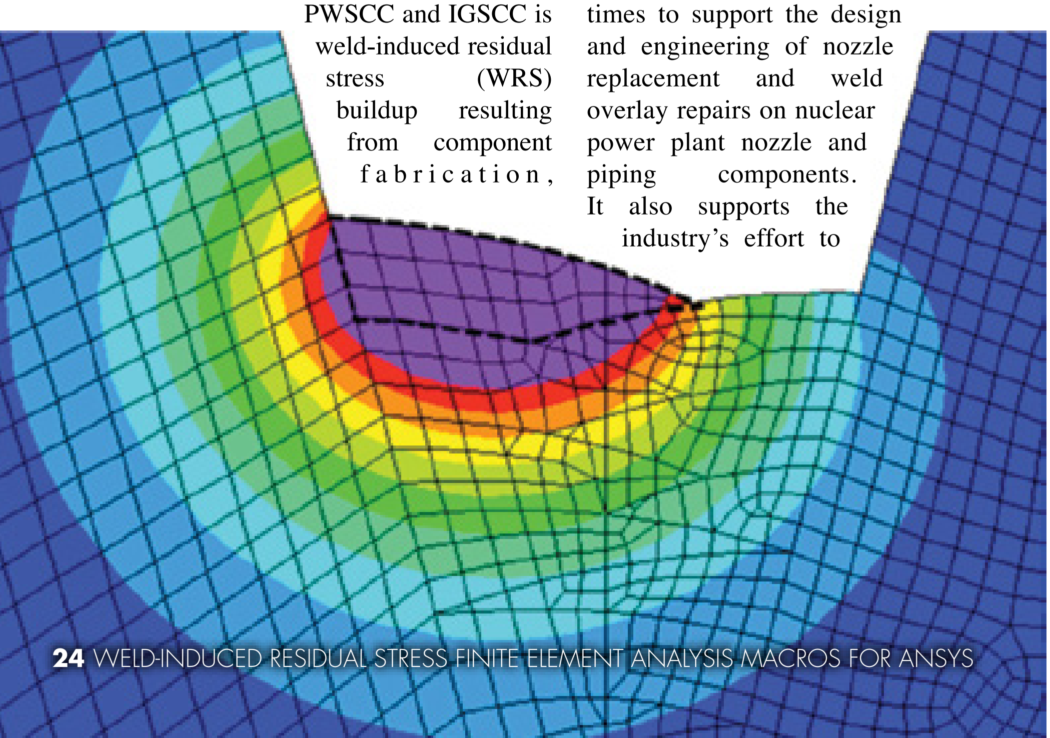
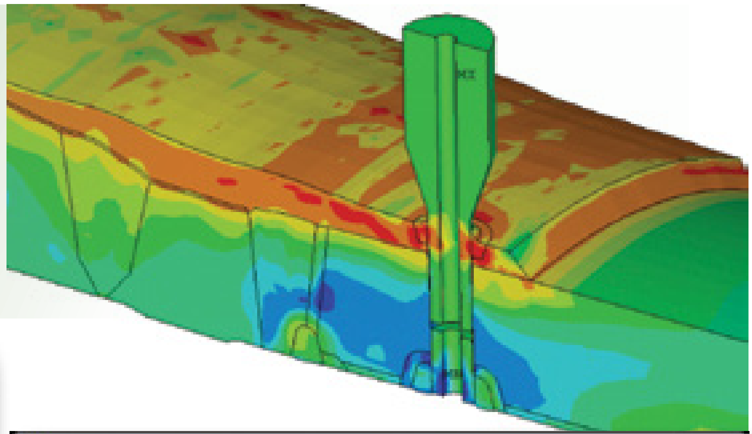


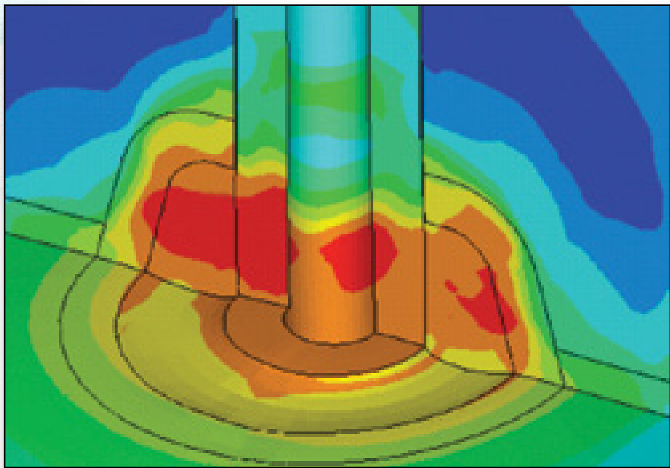
Utilizing sophisticated finite element analysis (FEA) to support accurate fracture mechanics evaluations has become an invaluable tool for the nuclear power generation industry to maintain component life while retaining adequate safety margins. Pressurized water stress corrosion cracking (PWSCC) and intergranular stress corrosion cracking (IGSCC) phenomena has been a major concern in the industry since the 1970s. One main contributor to PWSCC and IGSCC is weld-induced residual stress (WRS) buildup resulting from component fabrication, installation, and repair. As such, reliable and accurate predictions of WRS is a key input for use in flaw evaluations.

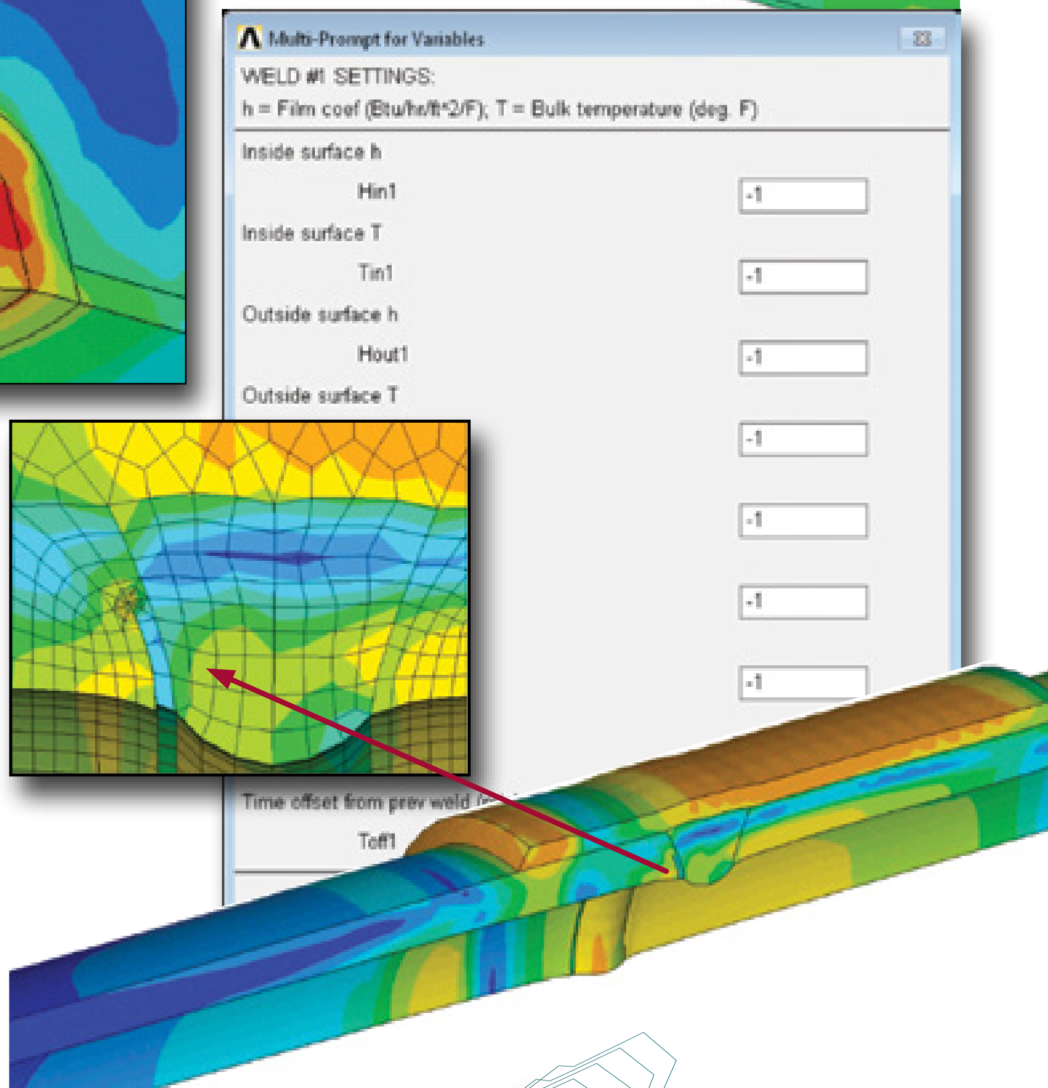
Structural Integrity Associates, Inc. has developed an automated WRS FEA process that integrates with the ANSYS Parametric Design Language FEA software to reliably and accurately predict WRS under plant operating conditions. Our process has been used numerous times to support the design and engineering of nozzle replacement and weld overlay repairs on nuclear power plant nozzle and piping components. It also supports the industry's effort to improve the technology, develop new repair methods, and evaluate WRS improvement options through EPRI-and NRC-sponsored research programs.



The process is implemented through sets of unified macros for two-dimensional (2D) and three-dimensional (3D) models, which involve graphical user interface (GUI) based input dialogs to guide its user through entering welding parameters and analysis conditions. The macros provide a streamlined framework to automate the analysis setup, weld bead deposition and sequencing, heat propagation calculation, and resulting WRS predictions. It requires no user guidance to derive time step iterations and achieve solution convergence. Therefore, the user is free to focus on studying and optimizing when possible important parameters such as changes in heat inputs and welding directions.







In addition, the WRS FEA macros are developed using native ANSYS APDL code, so the process can be integrated with other ANSYS features to expand the analysis capabilities to perform complex FEA simulations.

Examples are:

- integrate with contact elements to evaluate distortion nonlinearity due to welding;
- integrate with large deformation to combine distortion-induced plasticity with welding;
- and integrate with crack modeling to investigate weld-induced impacts via elastic-plastic fracture mechanics.

We recently presented a webinar hosted by ANSYS, Inc. that provided more details on our unique WRS FEA macros, including live demonstrations of the 2D and 3D workflow. The recording of the webinar can be downloaded from the ANSYS website at: http://structint.com/ansyswebinar

EARLY DETECTION VIA ADVANCEMENTS IN ULTRASONIC TECHNOLOGY AND METHODS

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Structural Integrity's pursuit to provide unmatched quality of services and deliverables requires constant innovation to current field employed technology. Recently, our Technical Support Unit (TSU) has focused on advancing ultrasonic detection using state-of-the-art technologies and methods. The focus of our effort is to achieve higher accuracy with newer, more innovative sensor designs and methods to achieve earlier detection of incipient damage.

We routinely employ linear phased array (LPA), annular phased array (APA), and time-of-flight diffraction (TOFD) technologies for flaw detection in a variety of contexts that include dissimilar metal welds, girth and seam welds associated with high energy piping, and turbine rotor inspection. Separately, LPA, APA, and TOFD based inspections have their own advantages and disadvantages. However, when the three technologies are used in conjunction, a synergistic result is achieved. For example with the specific case of high temperature seam weld inspection, complete rapid inspection of the weld is provided by LPA inspection. APA inspection is then used to supplement the inspection by obtaining higher resolution images at localized weld locations. TOFD is considered to have a sensitivity which lies between the sensitivities of the LPA and APA techniques. TOFD is used as a supplement to APA and LPA scans by providing rapid, full weld inspection with an accurate measure of flaw depth and length size.

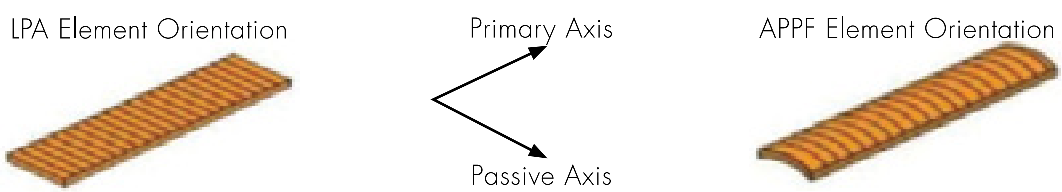

Figure 2. Comparison of LPA and APPF element orientation

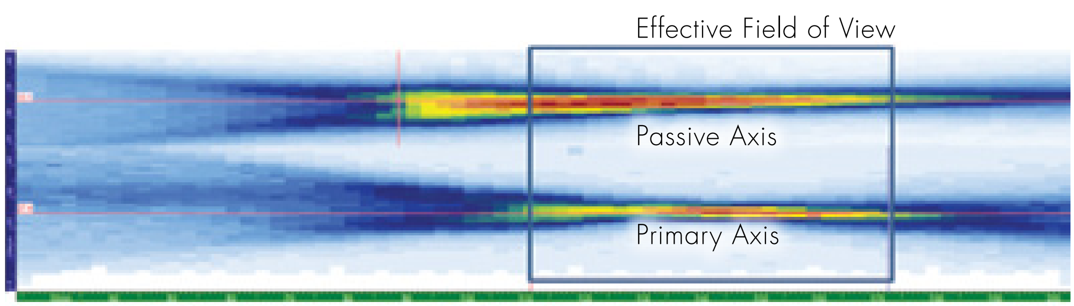

Figure 3. Axial beam plots of APPF phased array

ADVANCES IN LINEAR PHASED ARRAY TECHNOLOGY

Traditional linear phased array (LPA) probes are comprised typically of 10, 16, or 32 flat elements. These elements are linearly arranged and operate as both receivers and transmitters. When the elements are pulsed sequentially with small, precise timing delays, beam characteristics, like focus and steering, can be controlled. However, focus in the direction of the probe width, or passive direction cannot be controlled. With advanced passive plane focused (APPF) probes, curving of the probe elements induces a mechanical focus in the passive plane. This method of mechanical focusing is illustrated in Figure 2, and the results are shown in Figure 3. In reviewing the data collected with the APPF phased array, this increase in resolution has led to improved accuracy in flaw detection and length sizing. Figure 4 shows an example of the resolution increase with detection of cavitation in high energy piping with accuracy not previously obtained by LPA technology. The new APPF phased array still provides a much more efficient way of scanning entire areas, similar to LPA, but now with higher resolution. Additionally, the surface preparation needed is no more than required for most inspections and thus inspection times and costs are reduced, as compared to employing annual phased array.

Figure 1. Phased array turbine rotor inspection.

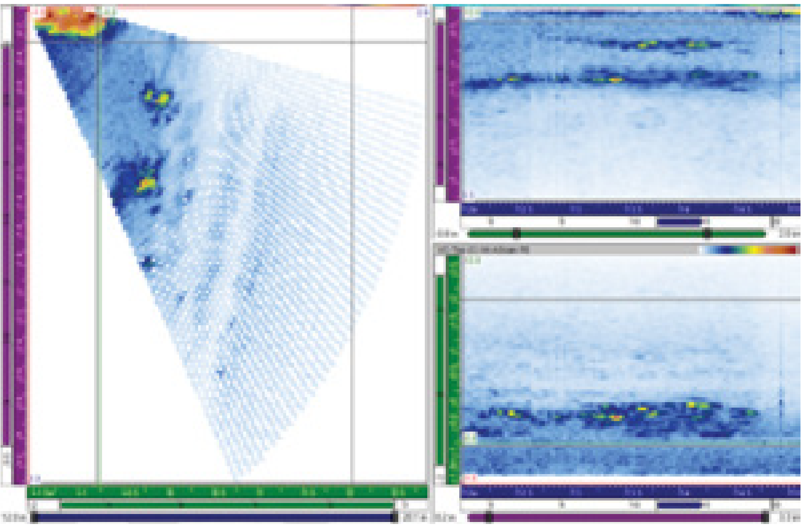

Figure 4. Detection of cavitation with APPF phased array technology

ADVANCEMENTS IN ANNULAR PHASED ARRAY TECHNOLOGY

APA technology takes advantage of spherical focusing to create a tight focal spot at specific depths in the inspection component. The tighter focal spot created from spherical focusing provides the ability to detect and characterize incipient levels of damage. Figure 5 shows a computer model created in the CIVA software package demonstrating the operational premise of an APA probe investigating a 3" thick steel specimen. To maintain the status of being an industry leader in early flaw detection and characterization, Structural Integrity has begun the modeling and testing of a new design of APA probes. Figure 6 shows simulated B-scan results of a new APA probe design versus a more dated probe design attempting to detect ten 0.008" side drilled hole (SDH) defects. As Figure 6 demonstrates, the new probe design is predicted to provide much higher inspection resolution. As is also illustrated in Figure 6, the tighter focal spot of the new probe design results in a 25% improvement in amplitude of the A-scan for the signal received from the third SDH. The conclusion which can be drawn from the modeled results is that the new probe design will be capable of earlier detection of incipient damage. Experiments on probes fabricated with the new design are now underway and their field performance will be evaluated this fall.

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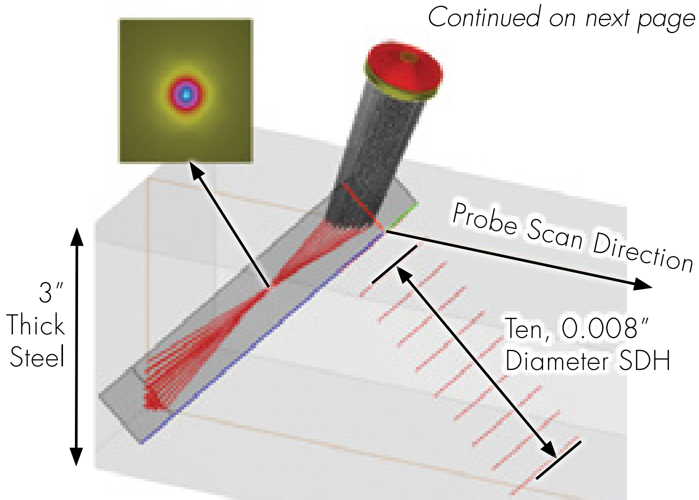

Figure 5. CIVA model of annular phased array probe operating with a 1.5" focal depth in steel

EARLY DETECTION VIA ADVANCEMENTS IN ULTRASONIC TECHNOLOGY AND METHODS CONTINUED

TIME-OF-FLIGHT DIFFRACTION TECHNIQUE

With TOFD inspection, a region requiring inspection is insonified with ultrasonic energy. By analyzing the signals received by a second, receiver transducer, the integrity of the insonified area can be determined. For example, in the case of a weld inspection, as per the Operating Principle section of Figure 7, a lateral wave traveling along the surface will be the first wave detected by a receiver. If a crack is present in the insonified weld area, the part of the crack located nearest to the top surface will diffract an ultrasonic wave and be detected by the receiver. Similarly, the crack tip located nearest the bottom surface will diffract a wave towards the receiver and will arrive at a time slightly later than the wave diffracted from the top of the crack. By analyzing the difference in the arrival times of these two diffracted waves (DW), the size of the crack can be deduced. With this method, the entire weld is scanned and an image is generated showing received time-of-flight as a function of scanning position. Once this plot is generated, the data is analyzed and regions with indications are noted as per the Data Collected During Inspection section of Figure 7.

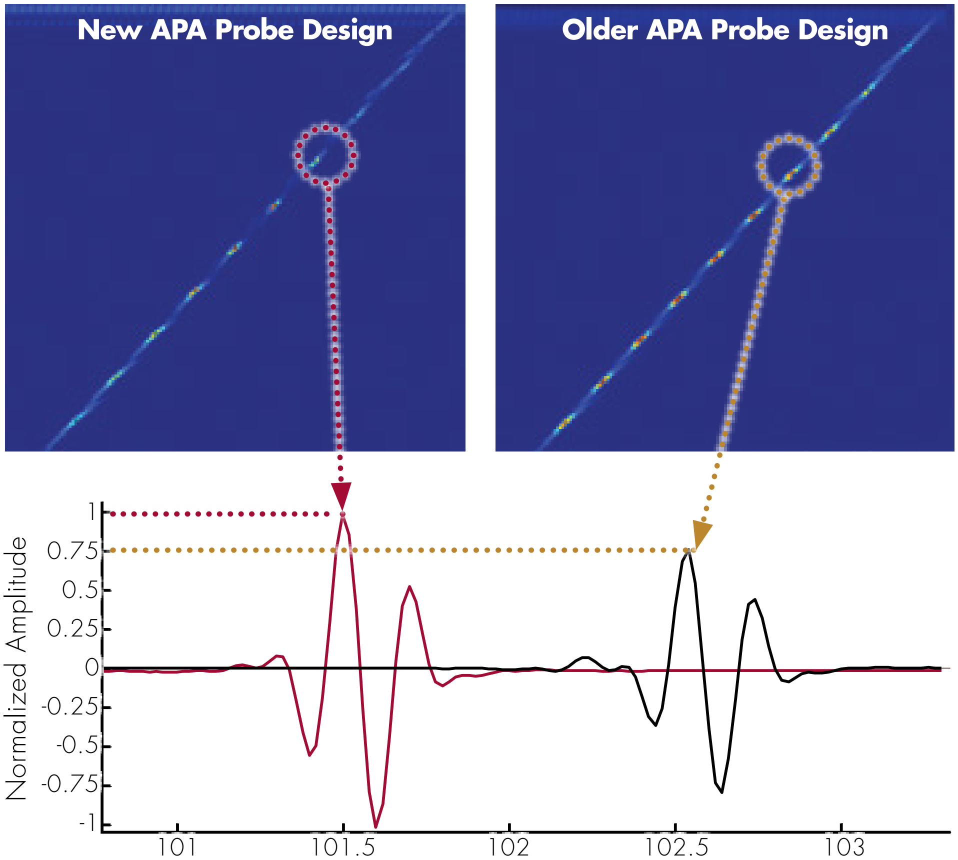

Figure 6. CIVA simulation of a comparison between new APA probe design versus an older probe design in detcting ten, 0.008″ side drilled holes. Simulated A-scans detected from reflection from the third defect show a 25% increase in signal amplitude.

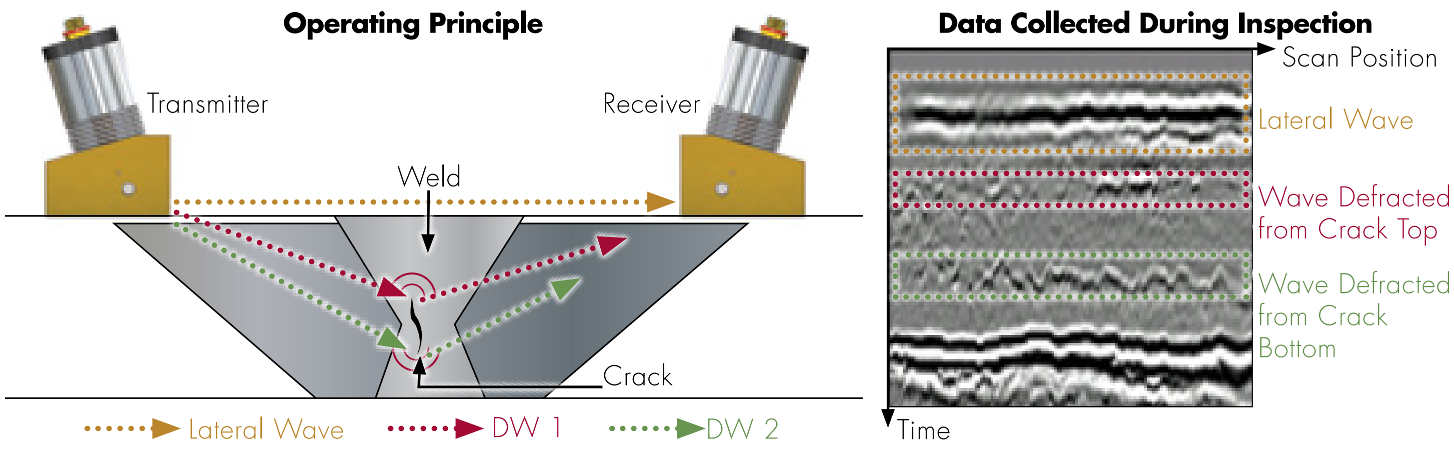

Figure 7. Operating principle of crack detection with TOFD and an example of data collected from inspection of service components.

CODE-COMPLIANT PHASED ARRAY ULTRASONIC EXAMINATION OF THIN AUSTENITIC MATERIALS

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One of Structural Integrity's industrial clients requested assistance with dispositioning potential weld discontinuities found during exploratory Radiographic Testing (RT) on some of their fabricated components. The main concern was potential for lack of fusion caused by the use of a low heat input Gas Metal Arc Welding (GMAW) to join thick to thin material sections. This particular weld configuration consisted of joining 4mm (0.158 inch) or 0.250 inch 304L Stainless Steel (SS) plate to 304L SS components with thicknesses of roughly one inch.

The macrograph shown in Figure 1 is representative of the weld configurations under investigation. Component fabrication was governed by American Welding Society (AWS) D1.6 Structural Welding Code- Stainless Steel. Structural Integrity and our client determined that a qualified volumetric examination technique such as Phased Array Ultrasonic Testing (PAUT) would be capable of increased sensitivity and sizing capability. Such a technique would be valuable for dispositioning and characterizing discontinuities. A new PAUT technique and procedure were developed for these unique weld configurations and material thicknesses.

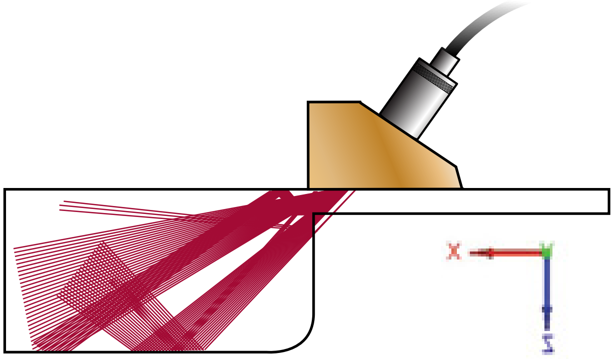

Figure 2. Modeled Reflections of PAUT for Weld Configuration (4mm plate)

Figure 1. Macrograph of Phased Array UT Development Sample Representative of Typical Joint Configuration (mm scale)

The developed ultrasonic technique used advanced phased array technology because it provides increased sensitivity to small indications. Prior to actual examination of representative mockup samples, we modeled and analyzed the weld configurations in CIVA as shown in Figure 2 and 3. The CIVA analysis showed effective UT coverage for the areas of weld requiring further interrogation. The technique was also required to encode the ultrasonic data for subsequent analysis and to provide a long-term record of the condition of the welds at the time of examination.

Procedure demonstration mockups were then developed using Electrical Discharge Machining (EDM) notches. These notches were placed at critical locations and depths that were difficult to direct the sound beams through including areas of largest expected weld metal grains, thereby validating

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CODE-COMPLIANT PHASED ARRAY ULTRASONIC EXAMINATION OF THIN AUSTENITIC MATERIALS CONTINUED

detection of discontinuities in all areas of interest in accordance with AWS D1.6 requirements. Further, the qualification of the PAUT procedure was based on detection of actual welding indications, which were in locations with difficult access for the ultrasonic beams and through welded areas that would contain the largest expected weld metal grains. The PAUT technique was successful in finding these discontinuities as demonstrated in the micrograph in Figure 4, as well as others.

During the development phase, we conducted field trials at client facilities using the developed PAUT techniques to examine actual components. The purpose of the field trials was to provide data to verify that the proposed methods and techniques could be applied in the field. The field PAUT examination utilized the two developed procedures: 1) Angle beam PAUT and 2) 0 degree PAUT; The developed technique successfully interrogated areas of interest and resolved relevant indications. However, a lesson learned was that select indications signals were collected at gain levels where data was saturated. This issue complicated the application of amplitude-based acceptance standards required in AWS D1.6. This and other lessons learned from the field trials were incorporated into the final PAUT procedures.

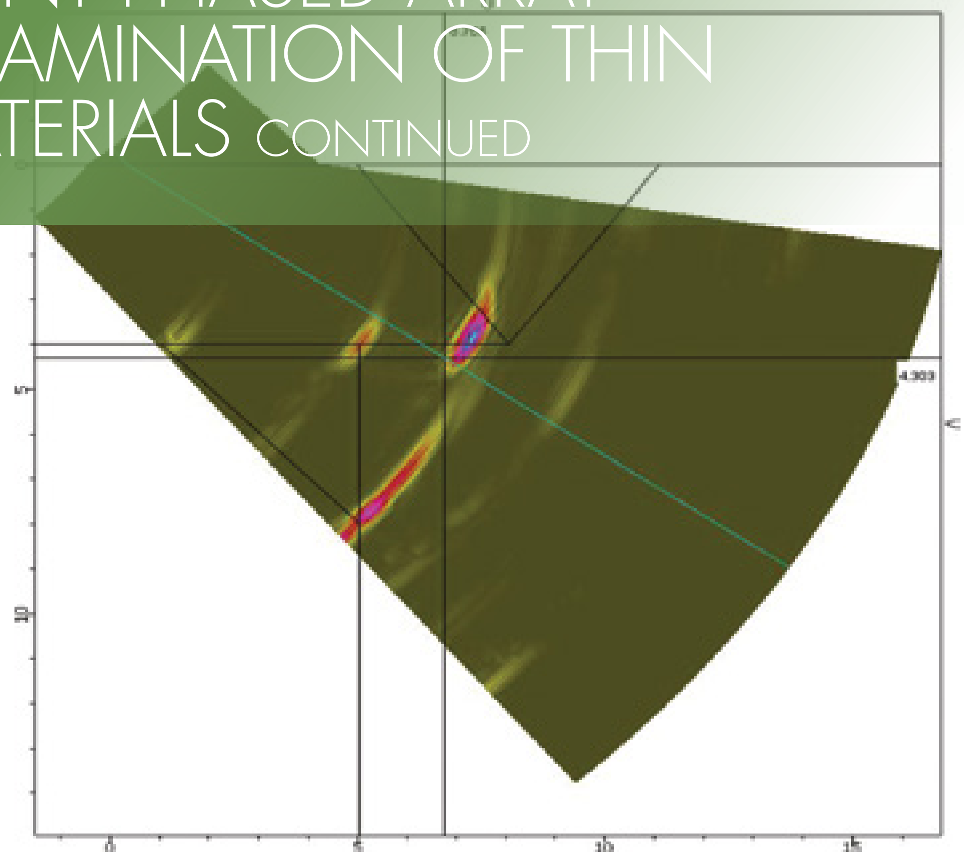


Figure 3. CIVA Output of Modeled PAUT

Significant challenges were overcome to develop a robust PAUT technique for these unique weld configurations and thin materials. The selection of an effective transducer frequency, wedge design, and UT search unit added to the development complexity. However, Structural Integrity and our client successfully developed a PAUT procedure qualified in accordance with AWS D1.6 with the ability to detect and resolve indications within complex configurations having significantly reduced section thicknesses. These efforts resulted in a Code-qualified volumetric examination technique and another set of tools available to assist in the disposition and evaluation of the weldments.

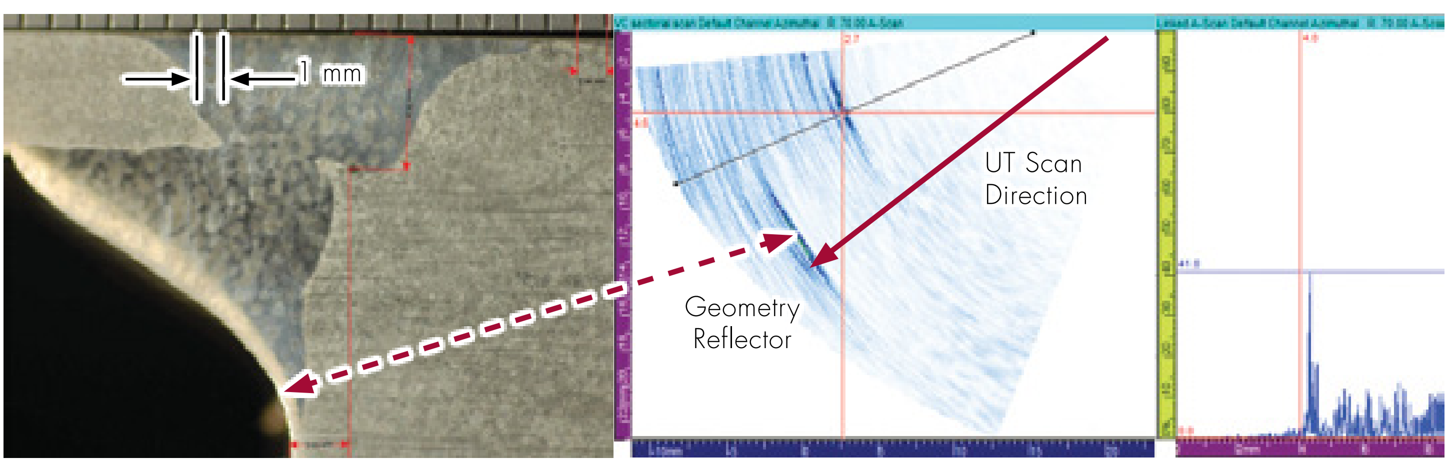
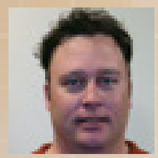


Figure 4. Cross Section of Fabrication Indication Found within the Qualification Mockup and the Corresponding Sectorial View and A Scan (mm scale).

STRUCTURAL INTEGRITY'S STRUCTURAL HEALTH MONITORING INITIATIVE



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In our continued efforts to set the industry trend in providing the best possible engineering, maintenance, and integrity solutions to our clients, Structural Integrity is currently implementing a strategic initiative to expand and grow our Structural Health Monitoring (SHM) service offerings to complement our well established nondestructive testing (NDT) capabilities.

NDT typically consists of sending personnel to a site to manually place sensors on a component to detect and characterize degradation. The sensors are then removed and, if re-inspections of the component are desired at a later time, personnel and equipment are remobilized to the site to re-perform the inspection.

An SHM approach also requires personnel to mobilize to the site, but, rather than placing the sensors on the component and then removing them when the inspection is complete, a sensor package is installed on the part permanently, such that re-inspections or monitoring of the component can be performed at any later time without requiring direct access to the component. Several advantages of SHM over conventional NDT are as follows:

- SHM solutions allow for the transformation of maintenance activities from time-based (during an outage or when the component is off-line or accessible) to condition-based (re-inspections, or monitoring, can occur at any time during operation or immediately after an abnormal event).
- Direct access to the component is required only once, at the time of sensor installation, which is particularly advantageous for difficult-to-access components or components in harsh operating environments. Examples include insulated or buried piping systems, pressure vessels or storage tank floors, high temperature components, and/or components inside high radiation or contaminated areas.
- As access to the component is required only once, tremendous cost savings can be realized by not having to continuously expose the component or send additional personnel and equipment to the site to perform re-inspections. Wireless data transmission capabilities allow for the possibility of remote monitoring.
- Improved damage detection and sizing: an SHM approach also allows for improved detection and sizing resolution as data sets can be acquired over time and compared to the initial baseline data set using data trending techniques to look for signal changes from the baseline state. The use of multiple data sets to look for changes in the sensor signal response over time, rather than having only one data set to look for a response from a defect, allows much smaller damage to be detected. This approach can be particularly useful for complex parts where the component material properties or geometry make it difficult to inspect and detect degradation using conventional NDT. Using SHM, the complexities of the part can essentially be subtracted out by comparing subsequent data sets to the baseline data set.

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STRUCTURAL INTEGRITY'S STRUCTURAL HEALTH MONITORING INITIATIVE CONTINUED

Our current SHM offerings are based on ultrasonic guided wave technology for piping systems, with future plans to grow our guided wave SHM capabilities to include other structures and components and incorporate new technologies.

GUIDED WAVE TESTING AND MONITORING TECHNOLOGIES

Guided Wave Testing (GWT) provides the ability to rapidly screen long lengths of piping for degradation from a single access point or test location. To complete a GWT examination, a transducer collar is placed on the piping to introduce mechanical stress waves (guided waves) which travel axially upstream and downstream of the transducer collar. When the guided waves impinge upon a change in the pipe's oth other components (tanks, etc.) cross section or stiffness, reflected wave modes are produced, which travel back to the transducer collar where they can be received and analyzed. GWT is particularly useful for detecting corrosion in inaccessible areas by placing the transducer collar on an area which is accessible. Typical examples include detection of corrosion under insulation, inside casings, or in buried piping accessed either via an excavation or from inside a vault or building to interrogate the buried section. Conventional GWT consists of placing the transducer collar on the pipe and then removing it upon completing the inspection. Guided wave energy is commonly introduced into the pipe using either piezoelectric (PZT) or magnetostrictive transducers.

Guided Wave Monitoring (GWM) differs from Guided Wave Testing (GWT) in that a guided wave transducer collar is permanently installed on the piping segment of interest. A baseline data set is acquired at the time of installation to which all subsequent data sets may be compared and analyzed for changes in the component. The permanently installed sensors are ideal for installation on piping in excavations, insulated piping systems, difficult-to-access areas, or on critical components. Several of the primary benefits of GWM over GWT include:

- Ability to re-inspect as often as desired without direct access to the component
- Improved sensitivity/coverage through the removal of coherent noise
- Improved sensitivity to corrosion at structural features (e.g., supports, welds, bends, etc.)
- Increased productivity, as there is no need to apply/remove the transducer collar
- Simplified interpretation through time-progression processing of data
- Added prognostic capabilities through data trending
- Conducive to condition-based, rather than time-based, maintenance

Several years ago, we began installing GWM systems primarily for buried pipe monitoring. For buried piping, systems are typically installed on an excavated segment of the line, which is then recoated and backfilled. At the designated location, an environmentally sealed GWT collar is adhesively bonded and sealed to the pipe. These GWT collars generate and receive the guided wave energy using multiple PZT transducers housed inside the GWT collar and spaced appropriately to excite the desired guided wave mode. These GWM systems can also be applied to above grade piping and/or insulated piping components.

Figure 1. Photograph of a gPIMS™ transducer collar, manufactured by Guided Ultrasonics, Ltd. (GUL), permanently installed on a pipe inside an excavation. The collar consists of a flexible circuit that is pre-molded in a low-profile polyurethane jacket to provide complete environmental protection. Next to the collar is a hard-wired connection box which can be routed to a suitable location above ground to allow continued data collection and monitoring.

Structural Integrity, in cooperation with our strategic ally, FBS, Inc., recently developed a new guided wave

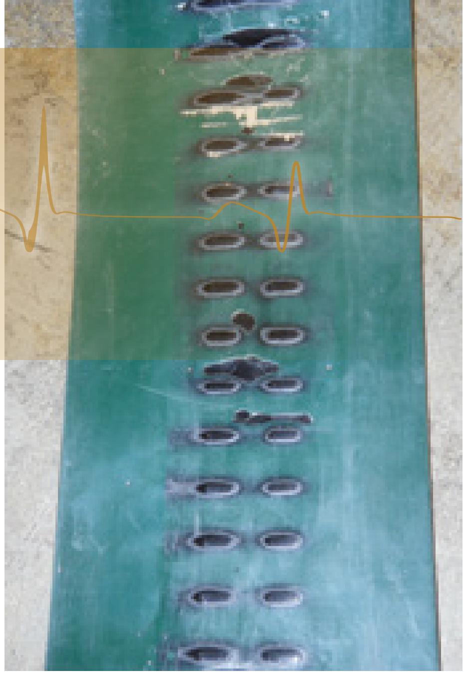


Figure 2. Photograph of the inside of a portion of a gPIMS™ transducer collar showing the locations of the PZT transducer elements used to generate and receive the guided wave energy.

focusing technology for permanent or temporary installation that is based on the magnetostrictive principle. Most standard guided wave tools use PZT materials to generate a guided wave in a pipe wall. In contrast, the magnetostrictive technique uses a magnetostrictive material (FeCo) that is bonded (either permanently or temporarily) to the surface of the pipe. A current-carrying coil is then used to cause perturbations of a bias magnetic field in the FeCo which subsequently causes mechanical vibrations to be transferred into the pipe wall. The result is an extremely low-profile (0.050 inches) phased-array transducer collar that utilizes distributed surface loading, as opposed to small localized loading, to practically eliminate the near field seen with traditional GWT collars, the nearfield being associated with the distance required to fully develop the ultrasonic beam to its desired form. This new technology will have a direct impact in the nuclear, fossil, and oil and gas transmission industries.

Recent advances in magnetostrictive sensor technology for GWT of piping have led to the development of a unique multi-channel transducer collar for the generation and reception of torsional guided waves. Figure 3 shows a conceptual illustration of the multi-channel magnetostrictive sensor array concept as well as a photograph of a commercialized version of this concept on an 8-inch diameter pipe. The collar shown in Figure 3 consists of eight circumferential segments with each circumferential segment consisting of two individually addressable channels for directional control [1].

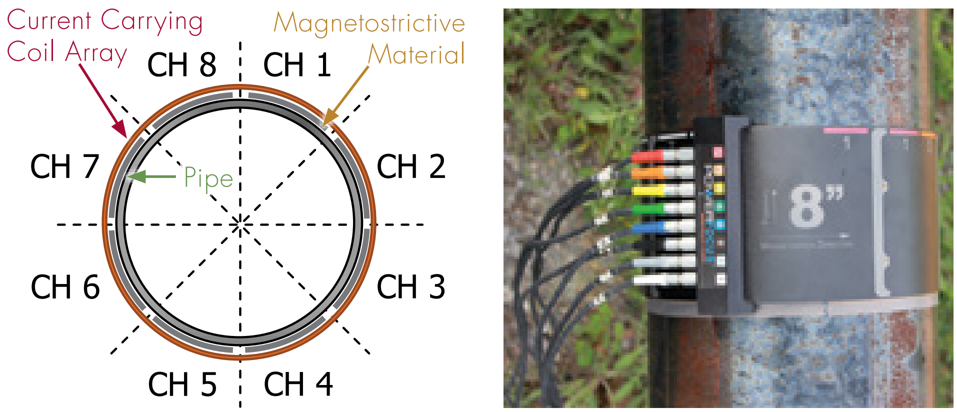
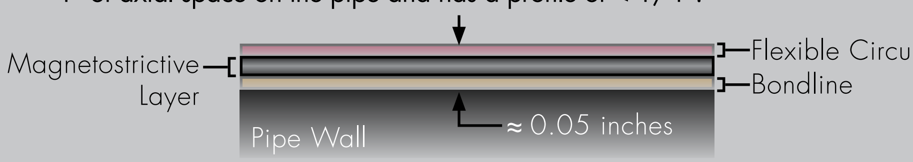


Figure 3. Conceptual illustration of the multi-channel collar configuration (left) and a photograph of an 8-inch collar showing the low profile (right) [1].

ADDITIONAL ADVANTAGES OF THE MAGNETOSTRICTIVE APPROACH:

1. **Distributed Loading** - Compared to the point loading of piezoelectric tools, the magnetostrictive approach results in distributed loading over the entire pipe circumference at the sensor location, which results in purer mode generation and a significantly decreased near field length; approximately 1ft compared to 3 ft to 5 ft for conventional PZT tools. This can be advantageous for areas such as wall penetrations or casing entrances, where there is not a sufficient amount of space to place a collar so that the near field does not extend into the penetration or casing, yet the penetration or casing area must still be inspected.
2. **Small Footprint** – A typical magnetostrictive sensor requires no more than 4" of axial space on the pipe and has a profile of < 1/4".



3. **Structural Health Monitoring (SHM) Capability** – Because the Magnetoelastic Focusing (MEF) sensors require a strip of FeCo to be bonded to the pipe, the technology naturally lends itself for use as an SHM sensor. By leaving the FeCo strip on the pipe, subsequent data sets from the same sensor can be acquired and compared to the original baseline data set to allow data trending over time. Functioning in an SHM mode to look for changes in the data over time allows for the detection of smaller defects and the interrogation of more complex geometries than can be obtained from a single data set alone, and in many cases the test range can be increased.
4. **Improved Sensitivity** –Tests performed with MEF sensors have demonstrated the ability to detect < 1% Cross Sectional Area (CSA) reductions in laboratory conditions, which is far superior to the ~3% CSA sensitivity achieved with standard guided wave tools on the same test pipe. This improved sensitivity can be attributed to the better Signal to Noise Ratio (SNR) achieved by the distributed loading attributes discussed previously. The detection of even smaller CSA reductions is possible when used in an SHM mode of operation.
5. **Cost Effectiveness** – Because the magnetostrictive technology does not incorporate costly piezoelectric materials, the sensor collars can be manufactured more easily, with fewer parts, and at a significant cost savings when compared with other permanently installed monitoring systems.

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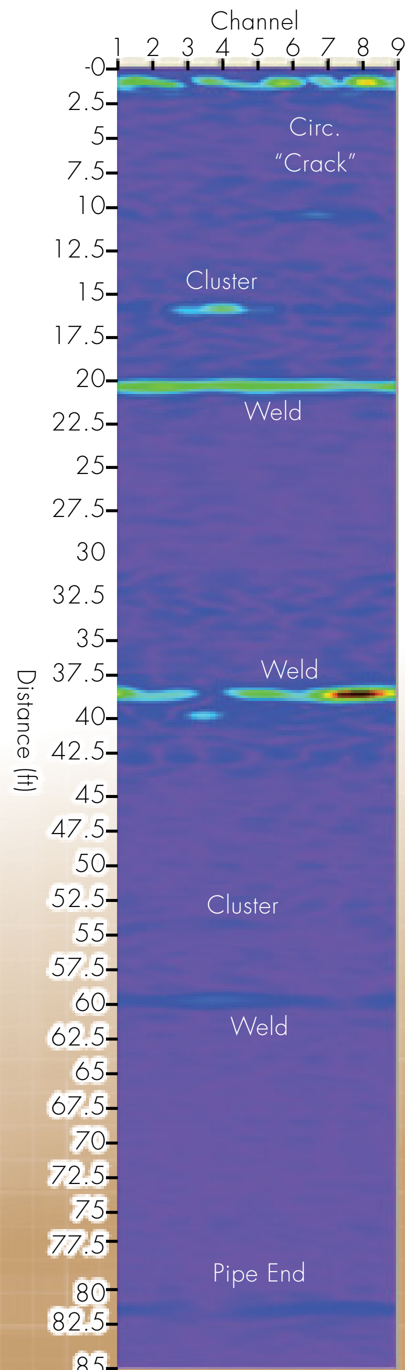


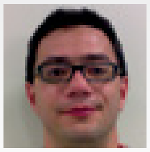
Figure 4. Pipe "image" generated using the Total Focal Scan™ capability of the PowerFocus™ system with the MEF sensor.

Integrated with the PowerFocus™ guided wave system, the MEF sensor concept has significant advantages over traditional magnetostrictive methods in that it allows for the phased excitation and segmented reception of guided waves, making flexural mode analysis and guided wave focusing possible. Figure 4 shows an example Total Focal Scan™ result obtained with the MEF technology. It is observed that each defect is clearly identified at the correct axial and circumferential location in the pipe. Estimating the circumferential extent of a defect is critical in determining the severity of said defect as a defect concentrated to a small circumferential location is more critical to the operability of the pipe than a defect of the same CSA that is distributed over a large circumferential area.

Ultimately, the MEF sensor technology, integrated with the PowerFocus guided wave inspection unit and software, allows Structural Integrity to offer another value-added technology to our clients, making permanently installed SHM solutions more accessible to a wider range of clientele.

Figure 2. – SI Engineers Deliver TTVMS to Korean Clients

Structural Integrity Delivers First Torsional Monitor to Overseas Client



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In May of 2013, Structural Integrity provided torsional vibration monitoring services to a Korean nuclear power plant following the installation of a new low pressure (LP) turbine and generator. As a precursor, a new turbine analytical model needed to be developed. However, since the new LP stage was delivered by Alstom and the new generator was designed and built by Doosan Heavy Industries & Construction, potentially substantial uncertainty existed regarding the torsional natural frequencies of the turbine generator (TG) system.

For torsional vibration, the shaker of the system is the generator, not the turbine. Therefore, a responsive mode by definition must have generator torsional deflection at or near the double line frequency (100Hz or 120Hz, depending on the geographic location of the power plant). In comparison, modes that do not result in generator deflection are benign and of no consequence to the reliability of the unit. Therefore, to avoid resonance conditions and potential damage to the newly installed equipment, the TG set must not have natural frequencies near the double line frequency.

An analytical approach can give good estimates of the natural frequencies. However, the quality of this estimate highly depends on the modeling parameters. Since the Korean TG set was delivered by different OEMs, modeling assumptions can further increase the uncertainty of the estimated torsional natural frequencies. The only way to really pinpoint the actual natural frequencies is to measure them during startup and to keep a close eye on those frequencies during initial operation.

Structural Integrity has developed a data acquisition system for just this purpose called the Transient Torsional Vibration Monitoring System (TTVMS). Our TTVMS can identify natural frequencies, mode shapes, relative magnitudes and phase differences, and monitor/capture torsional transients. If needed, it can also actuate an alarm in the control room notifying operators of elevated vibration levels.

TTVMS measures angular velocities at the selected locations with extreme accuracy using magnetic and optical probes. These sensors are not installed on the shaft; they are just masuring it from a distance. (See Figure 1 for illustration of the TTVMS principle of operation.) Traditional torsional vibration sensors, such as strain gauges, require more complex installation, on-board power sources, sophisticated telemetry, slip-rings and other hardware. In addition, due to power constraints, they cannot easily be used for long-term monitoring of torsional vibration levels.

The utilization of simple and robust angular velocity sensors results in an easy and fast system deployment of the TTVMS. Following multiple successful domestic installations, once again TTVMS has proven its value by providing important information to an overseas customer.

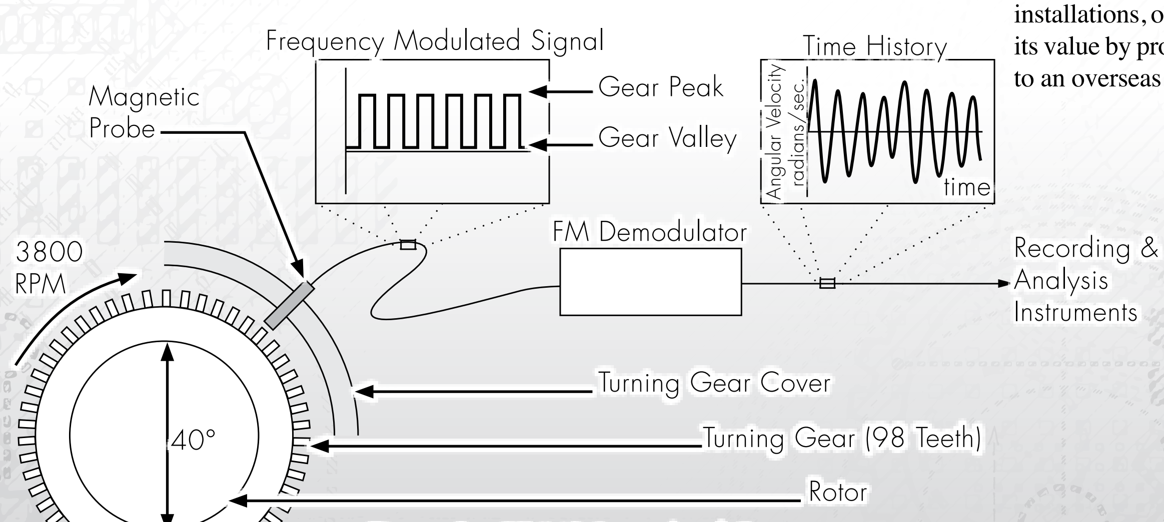

Figure 1. - TTVMS Principle of Operation

Success continues with International Clients and Partners

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TEAM SELECTED TO PROVIDE WATER JET PEENING SERVICES

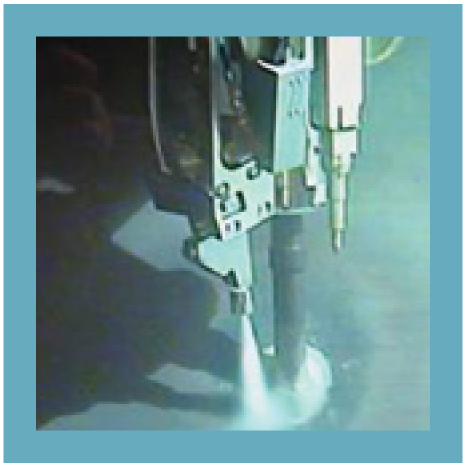
Contracts have been awarded by Callaway and Wolf Creek to the team of Mitsubishi Nuclear Energy Systems (MNES), Mitsubishi Heavy Industries (MHI), AZZ WSI, and Structural Integrity Associates, to provide state-of-the-art water jet peening services planned for 2016.

Each member of this team brings valuable services:

- MNES will be responsible for overall project management
- MHI will provide the specialized tooling and equipment necessary to complete the projects, along with implementation parameters for water jet peening
- AZZ WSI and Structural Integrity will perform the on-site implementation work. In addition to field NDE, Structural Integrity will also provide engineering and licensing support.

The services to be provided will mitigate the potential for stress corrosion cracking of eight reactor vessel primary coolant loop nozzle welds and 58 bottom-mounted nozzle (BMN) locations for each plant.

Water jet peening mitigates stress corrosion cracking by imparting compressive residual stresses at and near the surface of treated components. MHI has successfully used this same technology on 45 different projects for 21 pressurized water reactors in Japan. A key advantage of water jet peening is that the entire process can be conducted underwater and uses only high pressure water. No foreign materials are introduced into the reactor and no heat is applied to the material. The equipment is controlled remotely allowing the procedure to be performed with low occupational doses. The work will be performed during a planned refueling outages in 2016.



These peening contracts represent the first to be awarded in the U.S. for what has been established as a mature technology in Japan. In addition, this is the first implementation of a pre-emptive mitigation for BMNs in the U.S. NRC approval for inspection relief following application of peening is currently being sought by EPRI via submittal of MRP-335 (topical) and MRP-267 (technical basis document). ASME Code action to address the process is also underway.

KERNKRAFTWERK LEIBSTADT WELD OVERLAY PROJECT IS EMERGENT SUCCESS

Late last year, Structural Integrity Associates and Aquilex WSI (now AZZ

About W(SI)²

W(SI)² is the team of AZZ Welding Services Inc. (WSI) and Structural Integrity Associates, Inc. (SI). This 25-year partnership started with weld overlay repair of BWR primary system welds (due to IGSCC damage). In recent years, this team has set the industry standard for the engineering, licensing, implementation, and inspection of Alloy 600 component repairs.

WSI) completed the nuclear industry's first weld overlay in Switzerland. The project was an emergent repair of Feedwater (FW) nozzle (N5) dissimilar metal weld (DMW) cracking at KKL.

Despite challenges of mobilizing for an international emergent repair, a near through-wall flaw on an unisolable location, and the first use of a weld overlay in Switzerland, the vendor and utility team were able to successfully complete the job safely and ahead of schedule.

Helpful to the project was the fact that KKL began investigating the use of a weld overlay years ago for a different FW location. Limited activities pertaining more specifically to welding and implementation paperwork were performed and provided the necessary template to develop the field packages for implementation. Meaningful discussion with their authority, however, did not occur at that time.

The project presented several significant challenges to the W(SI)² team, including high dose, restricted access, and a near through-wall flaw. A rigorous mockup plan was developed and implemented expeditiously that addressed these issues as well as regulator questions on ambient temperature temperbead welding.

W(SI)² overcame these challenges by designing an overlay that met all ASME Code requirements and could be applied to the nozzle and inspected using an automated Performance Demonstration Initiative (PDI) qualified procedure. The team also modified welding and machining equipment to fit within the restricted access envelope. Additionally WSI demonstrated a manual gas tungsten arc welding (GTAW) process to successfully seal a water backed through-wall flaw.

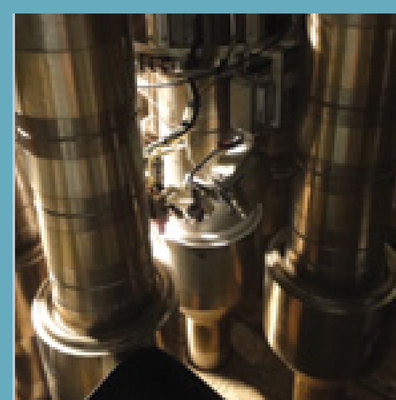
RINGHALS PRESSURIZER HEATER END CAP REPAIR

SI and WSI successfully implemented pressurizer heater end cap repairs at Ringhals (Sweden) Unit 2 during September/October 2012. Our scope of the work involved preparing an end cap design drawing, performing an end cap sizing calculation, and preparing an ASME Code-stamped Design Report. The report described the evaluations performed to determine the acceptability of an end cap repair for the pressurizer heater sleeve at Ringhals Nuclear Power Station, Unit 2, and provided details of the analysis, including a referenced stress analysis calculation, that demonstrated that the design complied with the requirements of Section III of the ASME Code, 2007 Edition with Addenda through 2009b.

Recognizing that some of the pressurizer electrical heaters would be replaced by Ringhals AB in the near future, Structural Integrity's design accommodated the possibility of one of the heaters getting stuck in either the heater guide tube (heater sleeve) or the heater support structure. If the heater got stuck and could not be fully removed from the pressurizer, then a contingency repair design had also been developed to return the pressurizer back to service without fully removing the heater. If such an incident occurred, the heater would be cut and secured in place before the end cap was welded into place. The end cap, along with the new heater sleeve-to-end cap fillet weld, would act as the new pressure boundary for the pressurizer.

OMEGA SEAL OVERLAY PROJECT COMPLETED OVERSEAS

W(SI)² completed the design, licensing support, and implementation of weld overlay repairs for 39 lower 'omega' seal locations, including two thermocouple locations, at an operating nuclear plant in east Asia. The lower omega seal is a seal weld between the Control Rod Drive Mechanisms (CRDMs) lower housing and its associated reactor head penetrations that is potentially susceptible to stress corrosion cracking.



The project was an emergent one, originally conceived to address only three locations, but then was expanded to first 21 and then to the full set of 39 lower omega seal locations. The project result was a highly successful one, both from a schedule and quality viewpoint. The original schedule for 39 locations was beat, and first-time quality was realized for all repair locations.

W(SI)² has completed numerous omega and canopy seal repairs over its long history, both in the U.S. and abroad. And with this latest project, the team demonstrated its relevance and viability for future emergent and planned repair needs for these components.

STRUCTURAL INTEGRITY ROLLS INTO NEW NDE TERRITORY WITH WHEEL PROBE

By: MATT ZIEGENHAGEN
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As a leader in nondestructive examination, Structural Integrity is always looking for ways to provide clients even greater accuracy and efficiency. A recent addition to our state-of-the-art toolbox -- the Sonatest Wheel Probe -- is helping us do just that.

SI has long been known in the NDE community for high-end phased array weld inspections. With the introduction of the wheel probe, SI brings its expertise to corrosion mapping.

Phased array wheel probes are best suited for manual or automated scanning of large, flat (or slightly curved) parts, covering large areas quickly and efficiently. The 50 mm Sonatest Wheel Probe incorporates a 64-element phased array probe with 0.8 mm resolution and a high-resolution position encoder for high-quality, high-resolution data capture.

Wheel probes also feature a wide, conformable rubber tire that is acoustically matched to water. This allows for high-quality results without the need for gel or large quantities of water.

The semi-automated probe uses a compressional wave to map and measure material flaws. The data can then be displayed in a variety of ways to identify flaw type, extent, position and depth. The wheel probe also features an encoding ability that makes it easier to revisit and monitor flaws for growth in future exams.

The sheer volume of data captured by the wheel probe surpasses conventional methods by leaps and bounds. For example, in traditional ultrasonic examinations, thickness measurements are generally taken about every inch, so a one-square-foot area would provide roughly 144 individual thickness readings. This is just a small fraction of the readings possible with a wheel probe, which can capture more than 119,000 readings in the same one-square-foot area in much less time. These additional readings can be output in tabular format for use in running pipeline remaining life models or can be used with appropriate post-processing software to generate B-scan or C-scan images mapping the degraded area.

For best results, the examination surface should be smooth and free of any loose debris or other foreign material that could keep the ultrasonic energy from entering the component. While it is possible to conduct examinations over external coatings, the following conditions can impact the quality of the data:

- Excessive coating thickness, disbonding, flaking or chips
- Petroleum- or coal tar-based coatings
- Excessive external corrosion, pitting or other outer surface degradation
- Welds, spatter, dents and/or other surface undulations
- Any organic material (e.g., moss) that may have developed on the outer surface.

SI has now successfully utilized the wheel probe for a number of applications including penstock assessments, oil and gas pipeline corrosion mapping, and nuclear piping corrosion mapping. The Wheel Probe technology, which provides the field ruggedized and efficiency benefits of a conventional UT systems with the encoded and detailed analysis benefits of an automated inspection approach, will certainly prove useful for mapping corrosion in other structures and applications in the future.

Caffeine

By: *ERIC HOUSTON*
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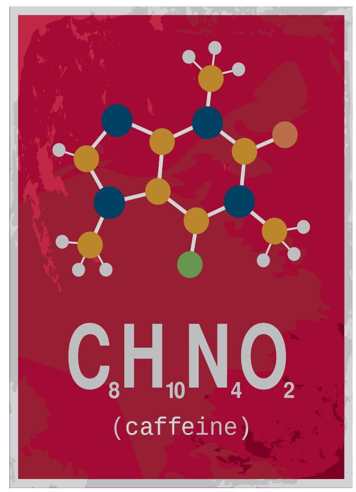
Approximately 90% of adults in North America use caffeine daily [1]. Caffeine "works" in two separate and interesting ways. The chemical adenosine is produced slowly throughout the day and essentially tells your brain to slow down and begin preparing for sleep. Caffeine blocks adenosine receptors in the brain. Adrenaline is produced in response to the sudden increase in brain activity as your body interprets this as some sort of emergency. Caffeine also bonds to adrenaline, which keeps the adrenaline in your system longer [2].

Caffeine has a slightly different effect on insects, where it is a potent insecticide (although caffeine builds up in the soil and can kill the plants you maybe trying to protect, so I don't recommend spraying your tomatoes with leftover Starbucks) [3].

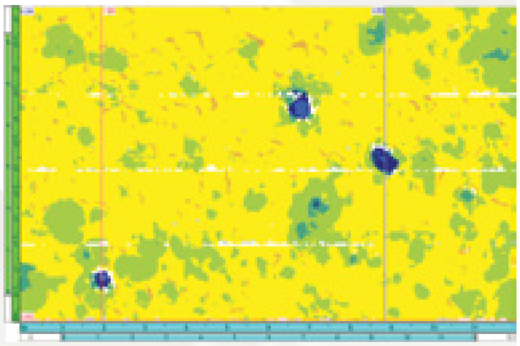


Caffeine is generally recognized as safe[4], but in large quantities it can be fatal. Ten grams taken orally is considered a lethal dose [5]. For perspective, there is about 260 mg of caffeine in a 12 oz. Starbucks brew [6]. So in order to ingest a lethal dose, you would have to drink almost 39 cups of coffee (that's more than 3 ½ gallons), and you would have to do it relatively quickly. Although caffeine is detectable in plasma five minutes after ingestion, the average half-life is five to eight hours in adults [5].

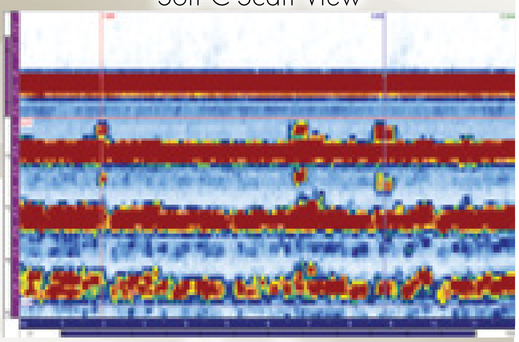
For many people, caffeine may pose a long-term health risk. If your daily consumption exceeds 500 mg, the Mayo Clinic suggests cutting back[7]. However, it seems highly unlikely that I'll hit the lethal dose today… I think I'll go get another cup of coffee.

REFERENCES:

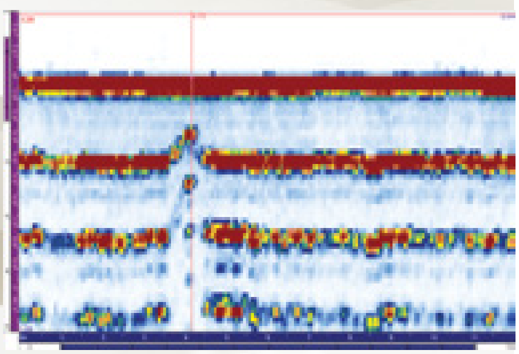
1. Lovett, Richard. "Coffee: The Demon Drink?" NewScientist 25 September 2005.
2. Discovery Health. "Why Does Caffeine Keep You Awake." Discovery Fit and Health, http://health.howstuffworks.com/wellness/drugs-alcohol/caffeine-awake.htm.
3. AP. "CAFFEINE IS NATURAL INSECTICIDE, SCIENTIST SAYS." The New York Times. The New York Times, 07 Oct. 1984
4. Code of Federal Regulations, Title 21 "Food and Drugs", Part 182 "Substances Generally Recognized as Safe," Section 1180 "Caffeine."
5. Yew, David. "Caffeine Toxicity." Medscpae, http://misc.medscape.com/pi/android/medscapeapp/html/A821863-business.html.
6. "Pike Place® Roast." Starbucks Coffee Company, http://www.starbucks.com/menu/drinks/brewed-coffee/pike-place-roast.
7. May Clinic Staff. "Caffeine Content for Coffee, Tea, Soda and More." Mayo Clinic. Mayo Foundation for Medical Education and Research, 01 Oct. 2011. Web. 23 July 2013. http://www.mayoclinic.com/health/caffeine/AN01211.



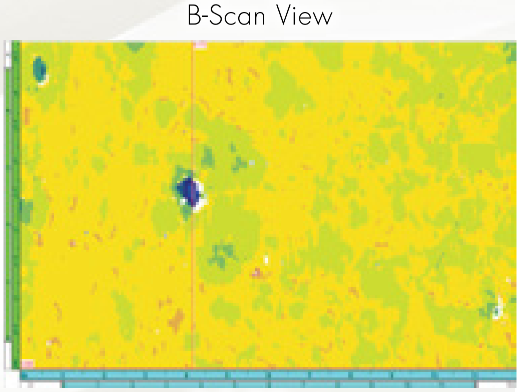
Data Set 1
Soft C-Scan View



B-Scan View



Data Set 2
B-Scan View



Soft C-Scan

State-of-the-Art Data Management Update

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In our last ***New & Views***, we announced that Structural Integrity had acquired the Tube Track application from Burns and Associates Engineers and was in the process of integrating it with our data management program SiCAMS. Combining the strengths of these two programs has resulted in the industry-leading data management program. Over the past six months we have made incredible progress.

Progress to date:

- We have finalized the name: "PlantTrack™". This acknowledges the long history of the predecessor TubeTrack application, while recognizing that the new functionality will allow tracking of many other plant components.
- Initially the program will focus on boiler tubing, providing a significant upgrade in functionality and performance to existing TubeTrack users and a very effective tool to systematically manage boiler tubing and high energy piping, building on the functionality from the legacy SiCAMS application.
- As we develop this new data management platform, we are already incorporating features that will expand functionality to include a wide variety of components, ranging from headers to feedwater systems to coal piping to – well, use your imagination!
- To prioritize some of these future developments, we will be working with our clients to meet their needs. Our long-term goal is to have the industry-leading data management program address all critical components throughout your plant.

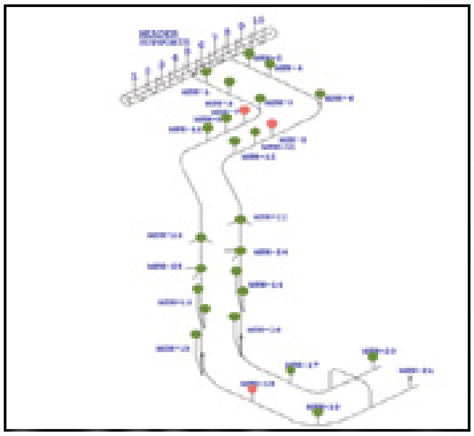
We are finalizing the boiler tubing and High Energy Piping, HEP modules and they will be ready for commercial applications by the end of the third quarter of 2013. A module to assist with the management of FAC data will be online by the end of the second quarter of 2014. We are working with several utilities to upgrade their Windows-based TubeTrack application to the new web-based PlantTrack suite. One of the new features introduced in PlantTrack is the ability to link data to any image, for example a scanned isometric drawing of a high energy piping system. Once this image is uploaded, data can be referenced to any location on the image. For example, weld labels can be located at girth weld locations. These weld labels will have all the same interactive capabilities as those created as part of a fully digital electronic drawing. These images (usually scanned drawings) will not have the true 3D capabilities, but allow an easy entry point to get started with data management for a particular system. At a later date, if needed, the image can be replaced with a true geometric representation of the system to take advantage of the full capabilities of PlantTrack.

We are finalizing standard database templates for HEP and boiler tubing modules utilizing our vast expertise on these areas. The templates would allow standardization across all applications in terms of types of records being tracked, as well as detailed information for each record type. We also realize that there are utilities who would like to maintain their way of tracking these records, so we have added flexible database setup features through which authorized users can specify new record types, fields and menus within their applications.

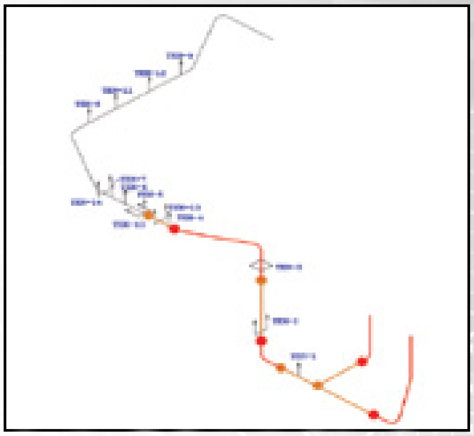
The new data filtering feature is used to easily display selected records graphically. TubeTrack's data filtering feature, "easels", has been significantly improved in PlantTrack to also be able to color code records based on the field values. The following example figures (below) demonstrate different ways the easels are used:

We have added easy to use filtering feature to query data across the unit, plant or fleet for reports and charts.

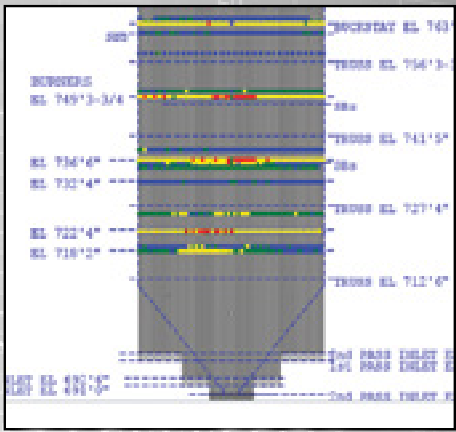
Structural Integrity will continue to keep you posted on the progress and how we can help you manage data for your critical plant components using PlantTrack.



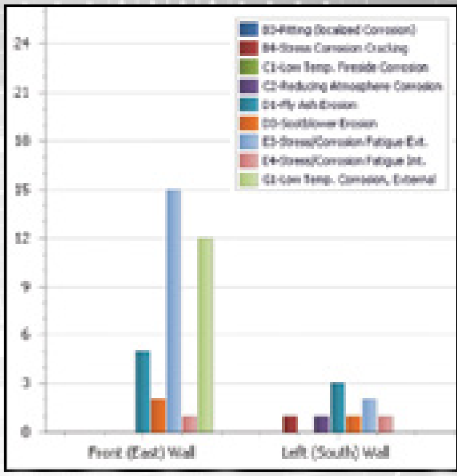
Example displaying hanger inspection results



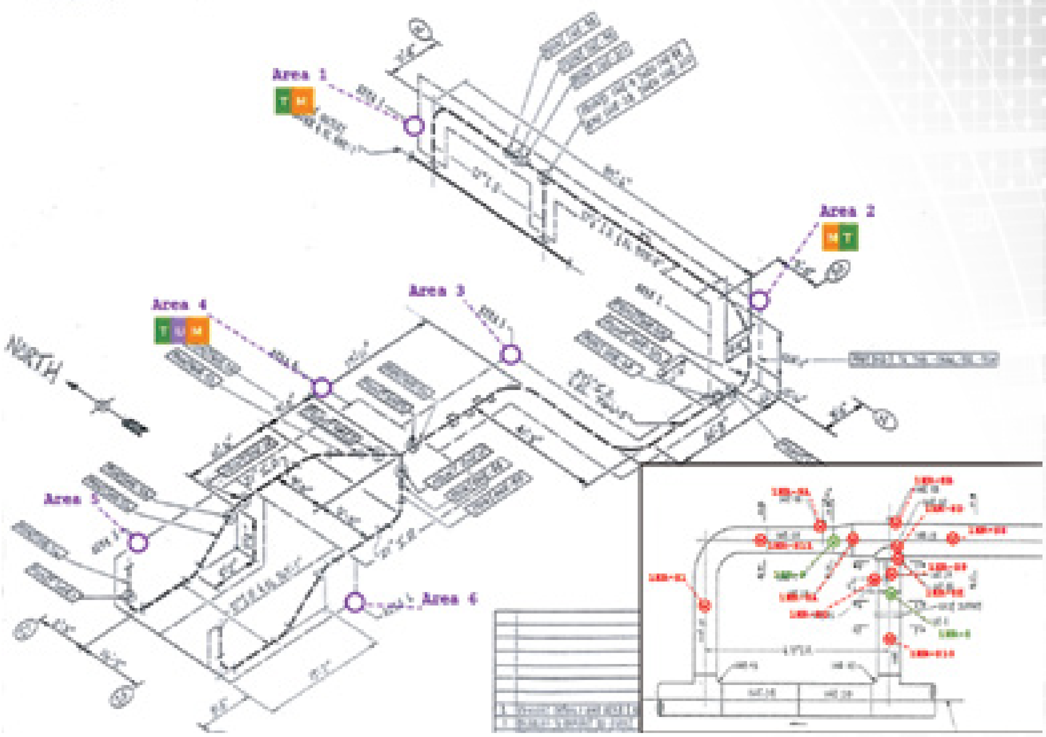
Location of asbestos insulation along the piping system



Typical waterwall displaying over 4,000 color coded NDE readings

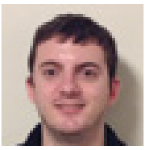


Typical bar chart for various types of failure mechanisms



Above is an image of a typical system with the overlaid weld labels.

A Case Study for Penstock Lap-Joints



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Structural Integrity recently completed a turn-key engineering project in support of Ontario Power Generation's (OPG's) effort to improve their capability to assess the condition of Sir Adam Beck 1 (SAB1) GS riveted penstocks, which are approaching 100 years of service. The project involved the completion of a critical flaw analysis for each of the various penstock plate thicknesses and the development, optimization, and field demonstration of a customized nondestructive examination technique to identify areas that may not satisfy the calculated acceptable flaw size criteria. The developed technique utilizes ultrasonic guided waves generated using non-contact electromagnetic acoustic transducers (EMATs).

BACKGROUND

Penstocks are large diameter pipe structures that control water flow to hydraulic turbines as part of the hydroelectric power generation process. The SAB1 GS penstock walls are fabricated from steel shells that vary in thickness along the length of the penstock (according to head pressure) and are secured together by longitudinal and circumferential riveted butt joints. The region where the penstock plate meets the outer butt strap is the critical area as water tends to collect in this area and run down the length of the joint, leading to crevice corrosion. Further compounding the issue, the external surface of the penstock is mostly inaccessible, as it is encased in concrete and buried below grade.

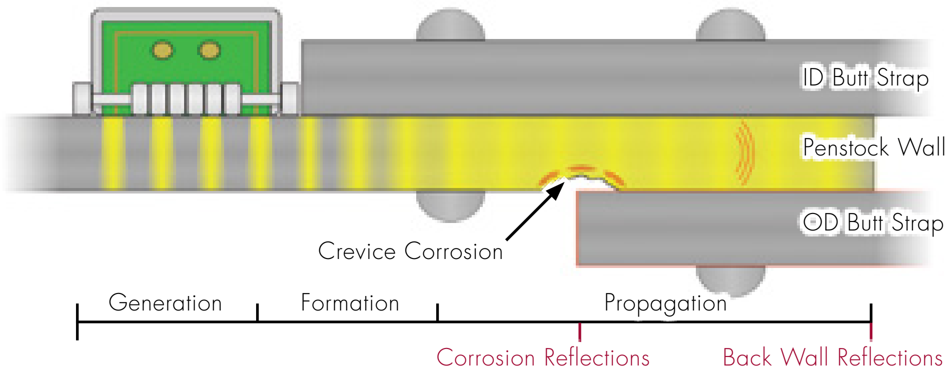

Figure 1. Conceptual illustration of the inspection technique applied to the SAB1 penstock.

THE STRUCTURAL INTEGRITY SOLUTION

Following the generation of a complete list of allowable flaw sizes for the varying penstock plate geometries, SI was tasked with developing a nondestructive testing method capable of evaluating the structure for areas of potential wall loss in violation of the allowable criteria. Several practical challenges needed to be taken into consideration in the development process:

1. Direct access to the area of interest is obstructed by the inner butt strap.
2. The inner plate surface is rough and pitted, which presents a challenge for liquid-coupled ultrasonic techniques.
3. The solution had to be applicable for plate thicknesses ranging from ½" up to 1 ¼".
4. The solution had to account for variations in the coupling pressure between the plates and butt straps that arise from the riveting process.

Our solution involved the integration of EMAT technology with customized data normalization and post-processing software. The process can be summarized in the following steps:

1. Assessment of the structure geometry, access points for inspection, and critical flaw analysis.
2. Survey and selection of applicable NDE techniques and sensors.
3. Theoretical and numerical modeling, including finite element analysis, to assess critical inspection parameters (i.e. damage sensitivity).
4. Mock-up fabrication and testing.
5. Data-processing software development and implementation.
6. Field demonstration.

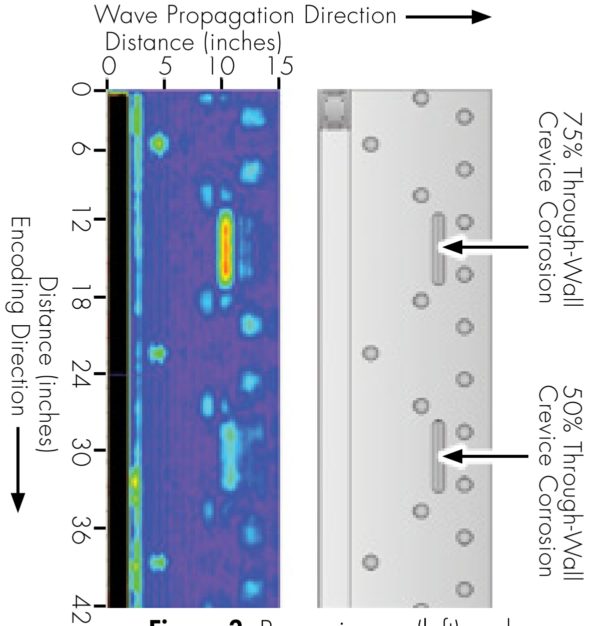

Figure 3. B-scan image (left) and schematic (right) of the quadruple-riveted penstock mock-up configuration.

Figure 2. Inspection of the SAB1 penstock longitudinal lap joint showing the EMAT probe connected to the handheld electronics.

Based on the joint configuration and the location of the area of interest, we determined that a guided wave technique was well-suited for this application. EMATs were chosen because they are non-contact and do not require liquid couplant; a feature that was critically important due to the rough, corroded condition of the inner penstock plate surface. The critical flaw analysis determined the sensitivity in terms of the smallest flaw size that the technique should be capable of detecting.

Theoretical modeling provided the dispersion curves for the geometry and material properties of the penstocks, which were used to select the optimal modes and frequencies for each wall thickness. The chosen combination of mode and frequency was used as input into finite element models to produce simulations of the wave propagating in the penstock and reflecting from rivets and areas of wall loss. A-scan data were extracted from the models to illustrate the sensitivity of the mode/frequency combination to varying quantities of wall loss.

Based on our finite element modeling results, mock-ups were developed with crevice corrosion type flaws. The mock-ups were assembled according to rivet specifications provided by OPG so the effect of the coupling pressure between the penstock wall and the butt straps on ultrasonic attenuation was accounted for. Experimental data was acquired and processed using internally developed software to execute data normalization and synthetic aperture focusing techniques (SAFT)and to generate enhanced B-scan images of the scanned area, like the one shown in Figure 3.

The software, generating what's shown in Figure 4, was designed to facilitate data processing and visualization by providing the following features:

- C-scan (color map), A-scan (horizontal graph), and D-scan (vertical graph) views.
- Moveable cursors for the user to select rivet indications to be used for data normalization (to remove the effect of coupling pressure variation).

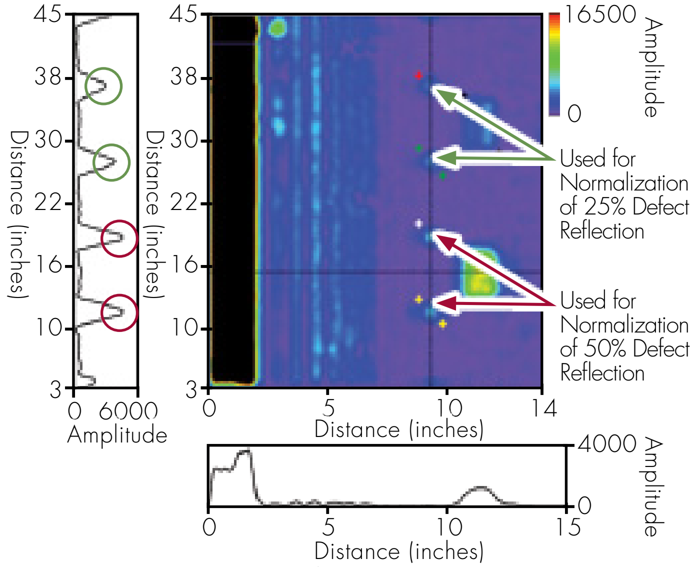

Figure 4. Screenshot of SI's internally-developed processing and visualization software

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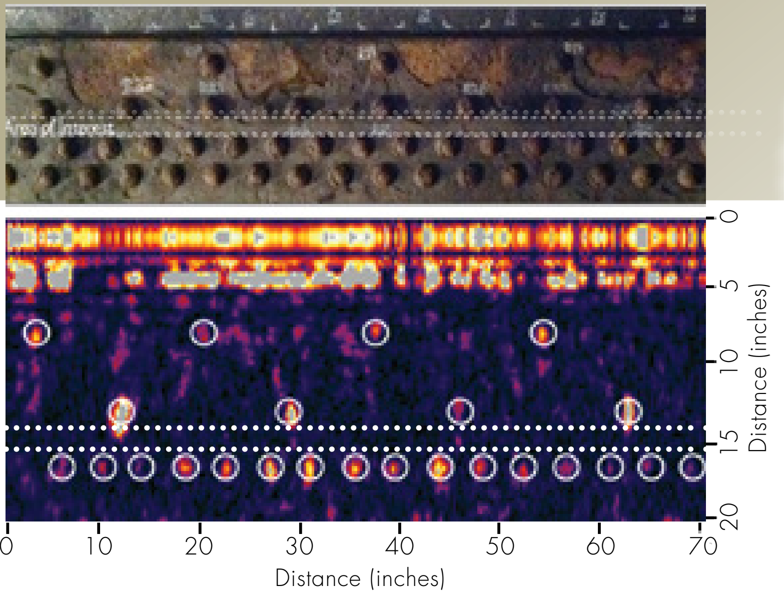

Figure 5. SAFT image (bottom) and photograph (top) from the inside of the SAB1 penstock taken along the upper edge of the longitudinal lap joint. The area of interest is between the two white, dashed lines.

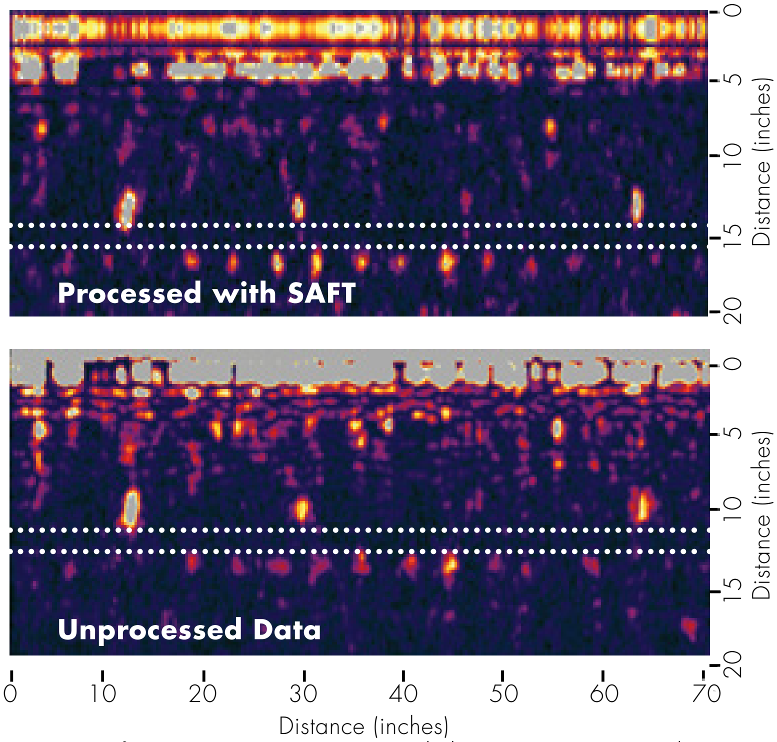

Figure 6. SAFT processed data (top) compared to standard B-scan data (bottom). The area of interest is between the two white, dashed lines.

FIELD DEMONSTRATION

After validating the technique through modeling and experimentation, and developing the necessary software for data processing and visualization, we prepared to take the technique into the field for demonstration. OPG arranged for a field demonstration on a longitudinal joint within one of the SAB1 GS penstocks.

For the field demonstration, we scanned one side of a longitudinal joint from within the SAB1 GS penstock. The technique successfully imaged most of the rivets and did not detect any areas of concern, as shown in Figure 5. After applying the SAFT algorithm to the data, the responses from the rivet holes further improved, as can be observed in Figure 6 by comparison of the SAFT and unprocessed B-scan images.

OUR RESULT

The detection and visualization of the third row of rivet holes in Figure 5 and Figure 6 provides confidence in the inspection, as this row is beyond the area of interest and the presence of the indications proves that energy is penetrating the joint area and getting coverage in the area of interest. If wall loss were present, the following would be observed:

1. Indications from the area of wall loss, as the change in thickness would produce reflections.
2. No indications from the rivets located immediately beyond the area of wall loss as a significant portion of the incident energy would be reflected back toward the probe by the crevice corrosion.

Hence, it can be concluded from the data in Figure 5 and Figure 6 that no significant wall loss was present within the area of interest at this particular longitudinal joint.

CONCLUSIONS

Through cooperation with OPG, Structural Integrity has delivered a comprehensive solution to a unique inspection problem for penstock lap-joints. The project culminated in a fully customized, field-ready NDE technique that will facilitate the lap-joint inspection process by identifying areas in violation of the calculated acceptable flaw size criteria.

The developed technique has been streamlined to facilitate rapid data acquisition and processing, while enhancing data quality. The cumulative result is a value-added solution for one of our customers that will maximize inspection coverage, minimize inspection time, and ultimately help OPG achieve their objective of obtaining data on a part of the penstock configuration which is of concern but that could not be inspected using conventional techniques.

Technology for the In-Line Inspection of Buried Pipe with Liners

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In-line inspection (ILI) with free-swimming and tethered tools, as well as robotically delivery devices, has been a common occurrence in the transmission pipeline industry for many years now, and this industry has made a significant investment in modifying their piping to launch and receive these inspection devices. Piping geometries in the nuclear industry, however, are typically much more complicated and, until recently, available ILI tools were not typically compatible with these piping systems. Further complicating the issue, piping in the nuclear industry comes in a great variety of diameters and materials and can have a number of different internal liners and potential fouling.

To help facilitate the transition of ILI technology into the nuclear industry, Structural Integrity (SI) has teamed with Diakont, developers of the RODIS robotic pipeline crawling system. Through this collaboration, SI and Diakont have and will continue to deliver new nondestructive examination (NDE) technologies that will address the unique piping challenges encountered in the nuclear industry. As an example, Structural Integrity is leveraging our internal group of NDE development engineers and researchers to integrate Pulsed Eddy Current (PEC) technology with the RODIS crawler for the inspection of cement lined piping. This advancement will allow for the through-liner inspection of cement lined pipe using PEC technology deployed on the RODIS crawler.

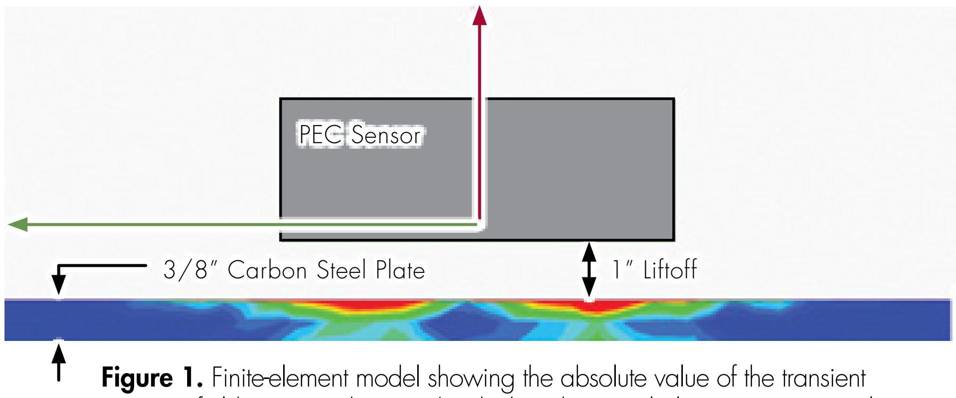

Figure 1. Finite-element model showing the absolute value of the transient magnetic field generated in a 3/8″ thick carbon steel plate using Structural Integrity's proprietary Pulsed Eddy Current sensor design. The sensor is located 1″ off the surface of the plate and full penetration through the thickness of the material is observed.

The PEC technique utilizes a pulsed magnetic field to extract information regarding the thickness of the material under investigation. As the magnetic pulse is injected into the ferrous material under investigation, transient eddy-currents diffuse into the material and result in a time-lag in the response of the material to the injected magnetic field. The duration of the time-lag is related to the material properties and thickness of the metal, thus providing a method for quantitative remaining thickness measurement. This sensor is ideal for interrogating underground, buried and piping encased in concrete for external metal loss.

The novel Structural Integrity Pulsed Eddy Current (SIPEC) sensor will have several advantages over existing commercial PEC sensor designs, including significantly improved spatial resolution and signal-to-noise ratio, as well as the ability to acquire data while in motion, a requirement for application with ILI tools. The SIPEC sensor design is based on a comprehensive understanding of electromagnetic theory, utilization of state-of the-art electronics, and has been optimized using finite-element modeling techniques. The first application of the SIPEC technology with the Diakont RODIS crawler is expected in the Spring of 2014.

The Critical Role of Advanced Ultrasonic Techniques

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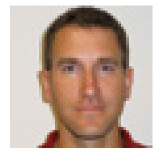

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In previous issues of ***New & Views***, we have discussed several essential elements of an effective High Energy Piping (HEP) program. These included prioritization of inspection locations using risk-based methodologies and the importance of performing accurate stress analysis of your systems (e.g., including the effects of creep redistribution). This article focuses on the role of ultrasonic inspections and how they are used to help achieve the goals of an HEP program, improved personnel safety and overall plant reliability.

After the HEP program has been established, inspection locations are typically prioritized using risk and consequence factors. Once these locations have been identified, an inspection plan is developed based on the welds selected, potential damage mechanisms present, and the appropriate nondestructive examination (NDE) method required for detection and characterization . Now it is time to perform field evaluations of the critical welds.

A variety of nondestructive examinations are typically performed to:

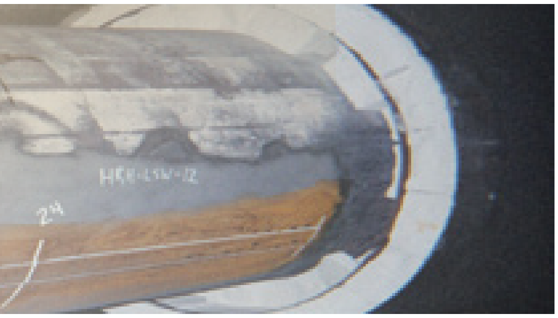
1. Establish the baseline condition of the weld and adjacent base material.
2. Determine the presence of service-related damage once the component has been placed in-service.
3. As a means of monitoring the propagation of damage detected in earlier examinations.

Each stage of the NDE process applies a slightly different level of rigor based on prior knowledge of the existing conditions present in the weld.

Re-inspections following a baseline or other prior inspection are used to identify changes in condition and estimate damage accumulation rates which, in turn, are used to refine remaining life assessments and optimize repair-replacement decisions. In addition, the evaluation of the inspection results will determine if there are any defects that could affect the short term safe operation and require immediate corrective action. If no defects are identified that need immediate corrective action, a life assessment of the welds is performed and a re-inspection interval is recommended.

APPLYING ULTRSASONIC TECHNIQUES

A combination of surface and volumetric NDE techniques are required to fully assess and determine the current state of the component being tested. Ultrasonic Testing (UT) techniques are primarily used for the detection and characterization of volumetric flaw conditions but are equally effective for flaws connected to the bounding surfaces of the component (i.e., outer and inner surfaces). Phased Array UT inspections are conducted today using digital instruments capable of presenting the ultrasonic signal responses volumetrically corrected using color coding for signal intensity. While the imaging features noted provide significant improvement when compared to conventional ultrasonic systems that only provide a single A-scan display for interpretation, they do not replace the requirement for a highly trained, experienced and seasoned UT examiner. In addition to an understanding of ultrasonic



principles, a knowledgeable examiner is well versed in the various materials manufacturing and joining processes, has an understanding of applied stresses within a piping system, as well as possesses a comprehensive understanding of the various service-related damage mechanisms that could be present.

As can be seen in Figure 1 the interpretation of the ultrasonic results can become challenging when multiple signal responses coexist in the same image display. In addition to the geometric signal responses from the weld root and counter-bore, there is a high probability for detecting both original fabrication defects and service-related damage in the same weld region. For these reasons, it is extremely important that the examiner be capable of accurately detecting and discriminating each indication type such that it can be properly characterized. Simply having the latest phased array instrument will not guarantee proper detection and characterization. To accomplish this requires an extensive technique development and procedure validation process to define the correct UT technique, and proper equipment selection in addition to the extensive training of examination personnel who have demonstrated proficiency and extensive practical experience.

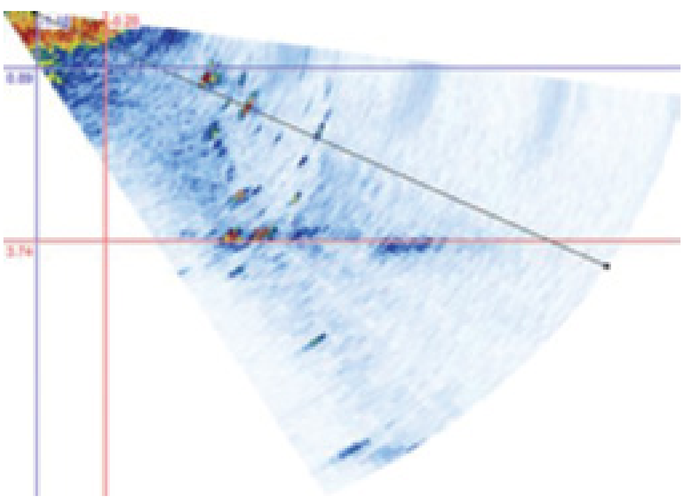


Figure 1. LPA image showing multiple indications

NDE PROFICIENCY DEMONSTRATION

The increased acceptance and broad use of phased array UT technology for HEP weld inspections was recently challenged by several major utilities, resulting in the development and implementation of a Fossil Power Plant NDE Proficiency Demonstration by the Electric Power Research Institute (EPRI). While the intended purpose of the EPRI program was to provide utility personnel with a higher degree of confidence in the use of phased array UT inspections, the unintended consequence exposed a significant expertise gap leaving the industry short on the number of validated procedures and personnel. **With more than two decades of practical experience in the use of phased array UT technology, Structural Integrity has successfully qualified the highest number of phased array UT examiners as compared to any other vendor under this EPRI program.** SI's accomplishments under this program not only improved customer confidence for our personnel performing phased array UT inspections, it reinforces the importance of extensive training and hands-on experience to achieve the highest probability of detection and accuracy in signal interpretation required for discrimination of critical flaws.

KEEPING A PERMANANT RECORD

HEP integrity management programs have existed for many years; as a result, most of the assessments performed today involve the analysis of the original baseline inspections with all subsequent re-inspections. Often times the previous NDE inspection reports provide very limited information about the inspection technique, findings or other details needed to conduct a valid comparison. The primary cause for insufficient details is due to the fact that most NDE is conducted without a permanent record of the actual inspection data being kept. In most instances, records are limited to handwritten data sheets with generic instrument calibration information and non-descriptive inspection results making it very difficult, if not impossible, to compare the two sets of results. Even with the advancements in technology today, most NDE reports are typically limited to a "screen shot" of a few points of interest as determined by the examiner.

Recognizing the added value that digitally recorded data provides, both during the initial inspection and for comparison during subsequent inspections, Structural Integrity adopted the use of fully encoded digital UT data beginning in the early 90s. Specific to HEP integrity management, our inspection protocol for UT was developed to provide full digital baseline data of the entire weld volume using a combination of encoded Time-of Flight Diffraction (TOFD) and/or Linear Phased Array (LPA). Additional

Continued on next page

HIGH ENERGY PIPING PROGRAMS

CONTINUED

high resolution inspection data can be attained by incorporating SI's Annular Phased Array (APA) ultrasonic technique, which is the only validated UT technique capable of accurately detecting and characterizing creep cavitation and micro-cracking. When applied using qualified inspection procedures, the combination of TOFD/LPA and APA provides the highest probability of detection, as well as the highest level of accuracy, for discriminating manufacturing and fabrication flaws from active service-related damage mechanisms.

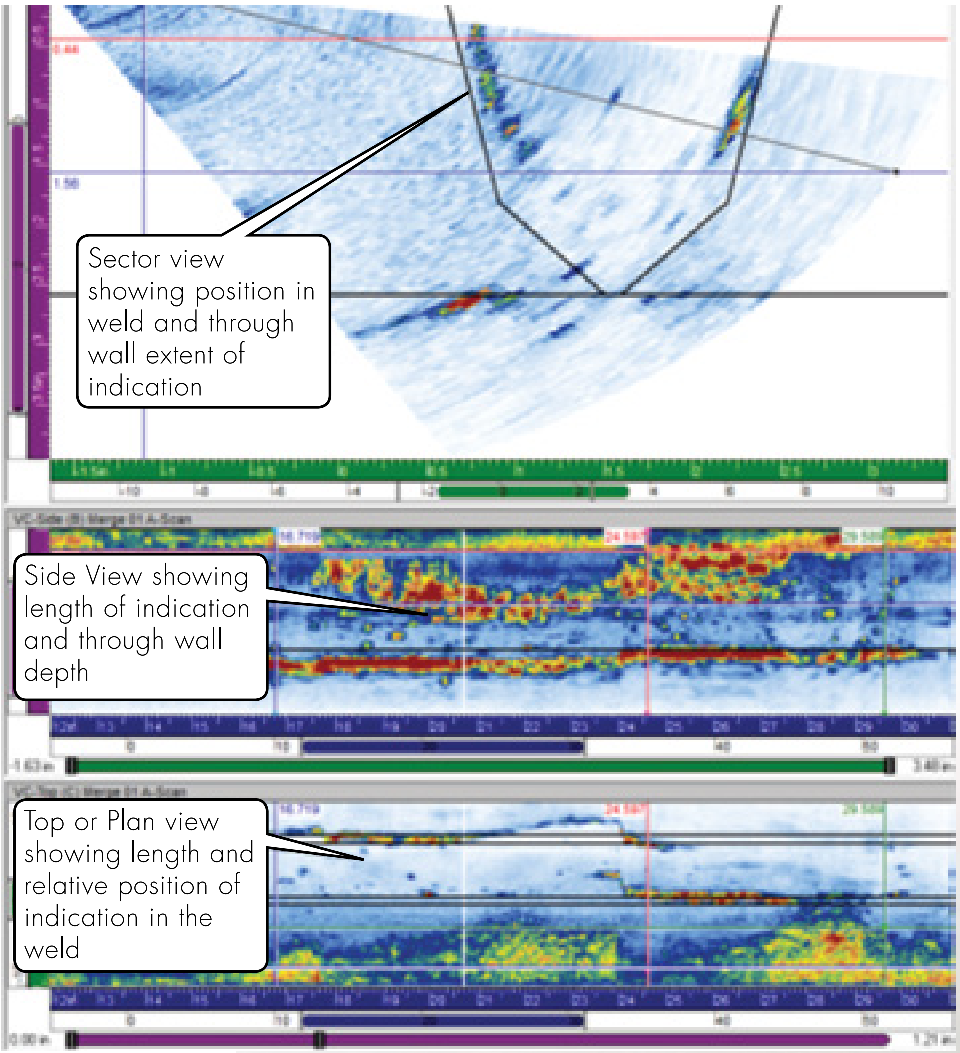
More recently, the value gained by use of these highly validated processes has been challenged by the desire to implement phased array UT inspection processes that minimize preparation costs, crew size, equipment requirements, and time spent by the examiner conducting and reporting results by reverting to the use of non-encoded LPA UT inspections. As described earlier in this article, while LPA may improve the visualization of the ultrasonic data, a non-encoded LPA inspection lacks the comprehensive analysis capability, permanent record, and future inspection data comparison benefits of a fully encoded UT inspection plan.

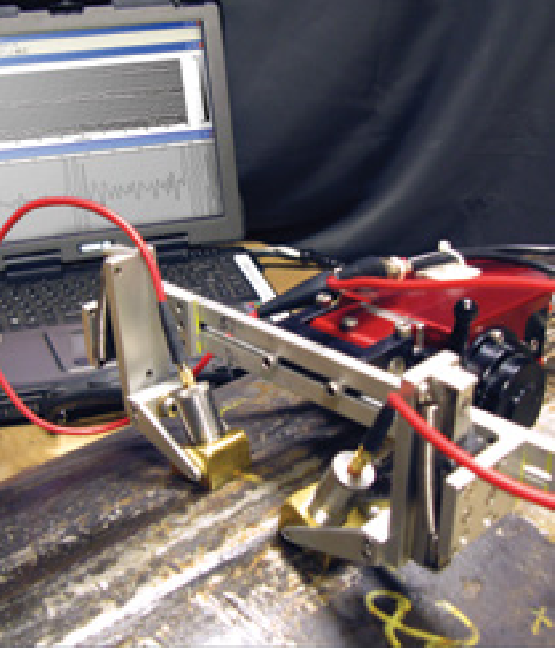
EXPANDED EXPERTISE

To continue providing the highest level of quality and confidence in our UT inspections, we expanded our internal Research, Development and Integration (RD&I) capability through the establishment of a strategic partnership with Feature Based Solutions (FBS) located in State College, Pennsylvania. In support of the strategic partnership, we opened an office in State College, adding expertise in material science, wave mechanics, and engineered solutions via mathematical and/or theoretical beam modeling. Studies completed by our RD&I team have led to the design and development of ultrasonic sensors and focal law configurations specific for the purpose of providing high precision for detection and discrimination of volumetric flaws. The ***News & Views*** article "*Early Detection via Advancements in Ultrasonic Technology and Methods"* describes some of the new UT technologies being developed and evaluated by SI. An advancement in LPA technology includes the advanced passive plane focused (APPF) probe.

Test data acquired using this advanced LPA technique can be seen in Figure 2. Advanced LPA sensor designs have been demonstrated to be superior to conventional linear arrays specifically for the purpose of flaw discrimination, positioning and through-wall depth measurements. Improved signal-to-noise allows for the use of elevated signal amplification, both during the inspection and in the post-processing of the digital data without masking low-level indications and maintaining the required signal fidelity. Based on data, acquired from the harvested HEP specimens (with varying degrees of service related damage) retained by the Materials Property Council at the University of Tennessee, the detection and characterization of

Figure 2. Data from advanced technique utilizing APPF technology





indications have improved when using the new APPF probes as compared to previous results using older technology products. Subsequently, we have completed several field assessment inspections using the advanced LPA technique for both new weld acceptance (ASME B31.1) and detection service-related damage in HEP girth welds. Further work using controlled specimens from two of EPRI's materials programs have produced very encouraging results that suggests the level for minimum flaw detection has improved over our standard linear array sensors. In addition to the advancements made in linear array sensor technology, our RD&I team has designed and are currently validating an advanced annular array sensor that incorporates the latest in sensor material and phased array system capabilities with expectations that this new sensor design will make its way to the field later this year.

OUR RESULTS

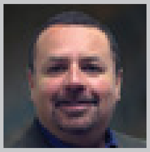
With the laboratory and field validation studies completed, Structural Integrity is now offering its customers a fully encoded LPA inspection process that incorporates the advancements in technology that have led to the success noted. Providing improved resolution, increased range of focus coverage, and a full digital record of the examination not only ensures the highest level of quality achievable but also supports future review and trending of examination results – all key elements of a successful high energy piping (or any other) life management program.

NACE International Cathodic Protection

Structural Integrity's employees take pride in being leaders and contributors in the industry.

Please join us in congratulating the following engineers in successfully earning, upgrading, or recertifying their NACE International Cathodic Protection training and certification this year:

CATHODIC PROTECTION – LEVEL II



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CORROSION SPECIALIST - LEVEL IV

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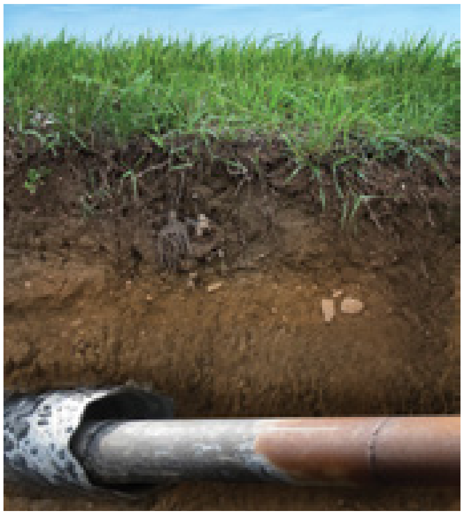

Congratulations also to Steve Biagiotti for his new NACE Technical Coordinating Committee (TCC) leadership appointment as the C2 Technology Coordinator (2013-2015) with oversight responsibility across industries for Technology Management Group C2: *Corrosion Prevention and Control for Pipelines and Tanks, Industrial Water Treating and Building Systems, and Cathodic Protection Technology*.

GIS ENHANCES AC MITIGATION PROJECTS

By: SCOTT RICCARDELLA
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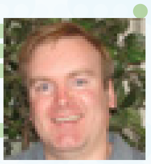

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Geographical Information Systems (GIS), like that shown in Figure 1, are a very beneficial tool to the pipeline industry for organizing critical asset information and key pipeline attributes. GIS is particularly useful for integrating and analyzing multiple datasets. Structural Integrity has recently developed specialized software tools to automate the integration of multiple data sets and generating map books. These map books can be printed or viewed with a ruggedized tablet in a field environment.

On a recent project, we used this approach for the documentation of AC mitigation systems as part of the construction support and as-built documentation. AC Corrosion is a special form of corrosion caused by stray currents discharging off a pipeline typically caused by inductive or conductive coupling due to pipelines being in close proximity to High Voltage AC power lines. This form of corrosion can require specialized mitigation systems to protect the integrity of the pipeline. The color maps were an invaluable tool to the construction teams, aiding in the installation of these mitigation systems.

Once the system designs were finalized, the GIS mapbooks provided added value over traditional CAD drawings via the:

- Ability to see a profile view of the system design relative to key reference points. Background aerial imagery makes it easier to identify transition, connection, and end points, leading to more accurate construction.
- Ability to see depth of cover, stationing, pipeline markers and other key pipeline attributes during construction for more accurate and efficient installation of the mitigation system.
- Ability to instantly generate an accurate representation of as-built construction data in an electronic and permanent record of the design that integrates with the client GIS system.
- Flexibility to incorporate and map future monitoring and survey results over time to ensure and trend effectiveness and/or issues with the AC mitigation system.

To help expedite development of these maps, Structural Integrity has created an application that assists in integrating data and creating the alignment sheet maps. Typical data captured and integrated includes:

- Depth of Cover
- GPS Coordinates tied to engineering or survey stationing
- GIS linear footage values
- Parameters of the AC mitigation system per configuration (such as ribbon type and quantity of ribbons, and tie-in points)
- Corrosion coupon locations
- Test stations
- Farm taps and appurtenances
- Exposed pipe, foreign pipelines, or other features identified from an on-site pipeline construction review

As new data is captured (such as from surveys or measurements from monitoring coupons), we can rapidly import this data and overlay it onto the existing data sets.

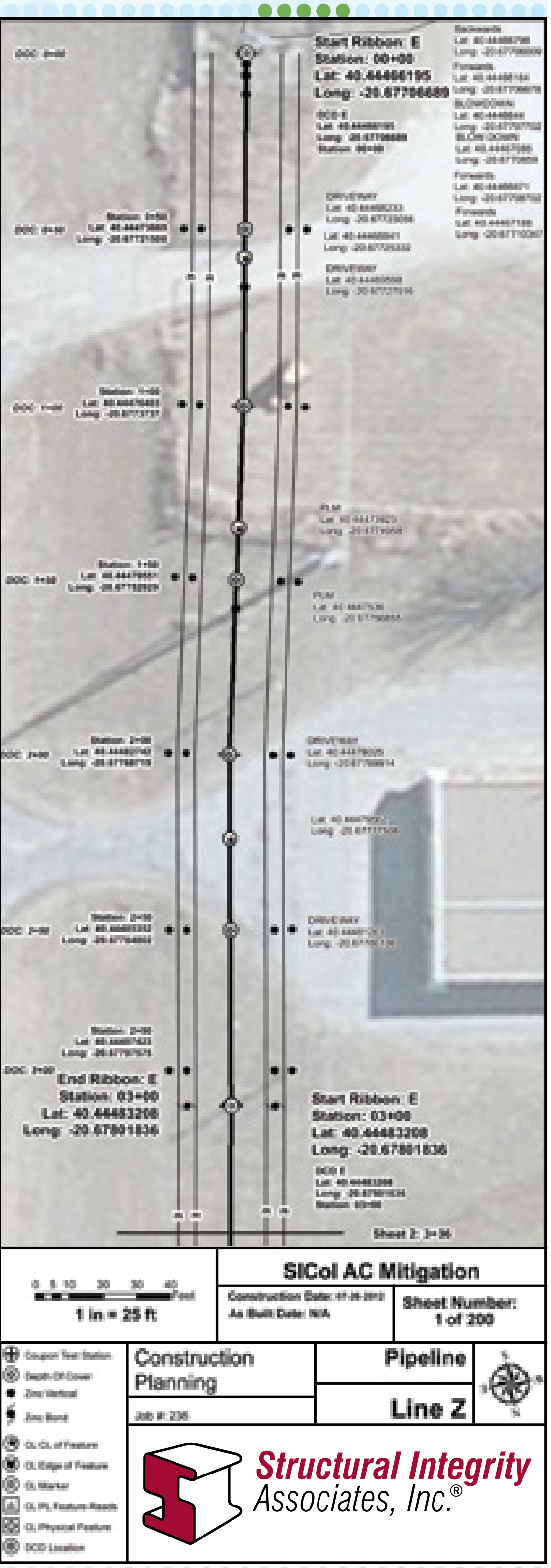
AC MITIGATION MODELING TOOLS

To help support our Cathodic Protection specialists on AC mitigation projects, Structural Integrity has recently acquired ELSYCA IRIS software for modeling the influences of AC corrosion and mitigation systems. This software provides the latest and most advanced analytical capabilities allowing greater details of the pipeline and HVAC system to be taken into account.

The analysis includes detailed modeling on the inductive and resistive effects and supports fast and easy import from files (such as coordinate databases, survey data, etc.). In addition, multiple pipeline networks can be modeled simultaneously and any pipe section can be used in combination with any coating quality.

http://structint.com/elsycairis

Figure 1: Below



ASME Organization and Code Processes

By: HAROLD E. QUEEN
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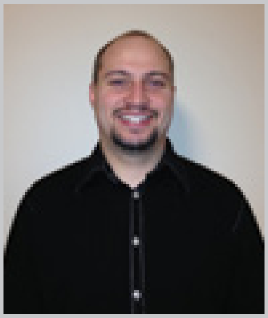

Since our foundation in 1983, Structural Integrity has recognized the value in industry code and standardization practices and has committed countless resources and time to ASME code development and maintenance as it relates to pressure vessels, piping nondestructive examination (NDE), and the power industry in general. While many of our senior level engineers can regularly be seen at ASME code meetings and conferences, SI is making an effort to get our younger engineers actively involved as well.

Matthew Lindsey, an engineer in Structural Integrity's NDE Research, Development, and Integration group, was recently awarded an ASME ECLIPSE internship for the 2013-2014 term. The ECLIPSE program promotes and recognizes the value of long-term leadership development and diversity among its members and is committed to investing in the careers of its high-potential early-career members. Interns learn their way around ASME with a dedicated advisor, where each intern is personally matched with a senior volunteer (as a professional coach) within their area of interest at ASME. In Matt's case, he has been paired with ASME's Director of Research.

Interns have the opportunity to travel to several meetings and participate in workshops and training sessions to build leadership and management skills, which will serve well in their professional and personal lives. There is a wide range of opportunities to network among themselves and senior society officers to see how they can incorporate the ASME experience into their career development. Matt has already participated in the 2013 Leadership Training Conference, the 2013 ASME Annual Meeting, and recently presented some of his work at the 2013 ASME PVP Annual Conference in Paris, France.

Based out of our State College, Pennsylvania office, Matt's early career has included projects involving piping inspection, bonded plate inspection, civil structure evaluation, and industrial components inspection. He has previously managed a project focusing on multifunctional ultrasonic rotorcraft sensors and, most recently, he has been developing novel inspection solutions that create value for the energy industry. Matt will put his experience to good use as an intern for the Center for Research and Technology Development (CRTD) at ASME.

Structural Integrity Associates, Inc.®

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Huntersville, NC 28078

TRADESHOWS:

NACE Corrosion Technology Week
Vancouver, Canada, *September 22-26, 2013*
Presenting: Steve Biagiotti

10th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components
Cannes, France, *October 1-3, 2013*
Presenting: Paul Sullivan, Harold Queen, Roger Royer

NAES Plant Managers Meeting and Vendor Fair
Bellevue, WA, *October 14-17, 2013*
Exhibiting

7EA Users Group Conference
Monterrey, CA, *October 22-25, 2013*
Exhibiting

International Water Conference
Orlando, FL *November 17-21, 2013*
Presenting: Amanda Robinson

EPRI Welding and Repair Technology Center Meeting
Savannah, GA *December 9-13, 2013*
Presenting

2013 EPRI Generation Advanced Nondestructive Evaluation Conference
Charlotte, NC, *December 10-13, 2013*
Exhibiting and Presenting

Energy Gen Conference
Bismarck, ND, *January 28-30, 2014*
Exhibiting

HRSG Users Group
Las Vegas, NV, *February 24-26, 2014*
Exhibiting

NEI R&D Summit (with Long Term Operation/ Subsequent License Renewal Workshop and Small Modular Reactor Forum)
Washington, D.C. *February 25-26, 2014*
Exhibiting

NACE Corrosion, Booth #2522
San Antonio, TX, *March 9-13, 2014*
Exhibiting and Presenting: Kamalu Koenig, Steve Biagiotti, Andy Crompton and Pete Wood

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